

FINAL REPORT

SXI PROTOTYPE MIRROR MOUNT

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1. ABSTRACT

This final report describes the work performed under the delivery order No. 87 from June 1993 to January 1995. The purpose of this contract was to provide optomechanical engineering and fabrication support to the Solar X-ray Imager (SXI) program in the areas of mirror, optical bench and camera assemblies of the telescope. The Center for Applied Optics (CAO) worked closely with the Optics and S&E technical staff of MSFC to develop and investigate the most viable and economical options for the design and fabrication of a number of parts for the various telescope assemblies. All the tasks under this delivery order have been successfully completed within budget and schedule.

A number of development hardware parts have been designed and fabricated jointly by MSFC and UAH for the engineering model of SXI. The major parts include a nickel electroformed mirror and a mirror mount, plating and coating of the ceramic spacers, and gold plating of the contact rings and fingers for the camera assembly. An aluminum model of the high accuracy sun sensor (HASS) was also designed and fabricated. A number of fiber optic tapers for the camera assembly were also coated with indium tin oxide and phosphor for testing and evaluation by MSFC.

A large number of the SXI optical bench parts were also redesigned and simplified for a prototype telescope. These parts include the forward and rear support flanges, front aperture plate, the graphite epoxy optical bench and a test fixture for the prototype telescope. More than fifty (50) drawings were generated for various components of the prototype telescope. Some of these parts were subsequently fabricated at UAH machine shop or at MSFC or by the outside contractors.

UAH also provide technical support to MSFC staff for a number of preliminary and critical design reviews. These design reviews included PDR and CDR for the mirror assembly by United Technologies Optical Systems (UTOS), and the program quarterly reviews, and SXI PDR and CDR. UAH staff also regularly attended the monthly status reviews, and made a significant number of suggestions to improve the design, assembly and alignment of the telescope.

Finally, a high level assembly and alignment plan for the entire telescope was prepared by UAH. This plan addresses the sequence of assembly, the required assembly and alignment tolerances, and the methods to verify the alignment at each step during the assembly process. This assembly and alignment plan will be used to assemble and integrate the engineering model (EM) of the telescope. Later on, based on this plan more detailed assembly and alignment procedures will be developed for the lower-level assemblies of SXI.



2.0 INTRODUCTION

The Solar X-ray Imager (SXI) is a telescope being developed to operate from orbit aboard a Geostationary Operational Environmental Satellite (GOES). Its mission is to monitor the X-ray spectrum of the sun and transmit video images to the earth in near real time. The precise alignment of the optical elements, accurate records of any misalignments-alignments and the stability of these elements over the mission lifetime is critical to the image quality.

The spacecraft will provide solar pointing platform and control to maintain the SXI boresight to the center of the solar disk to within 3 arc-minutes in elevation, and 3.5 arc-minutes in azimuth. The telescope will permit near real-time reconstruction of the solar images in the spectral range from 6 to 60 Å. The spatial resolution of the SXI is sufficient to allow reconstruction of solar flares, loops and coronal holes.

The telescope consists of a monolithic grazing incidence type mirror with a paraboloid and a hyperboloid sections in Wolter type I configuration. The mirror focuses an image of the sun on a x-ray image detector through one of a set of filters. A high accuracy sun sensor (HASS) is used to monitor the solar aspect angles relative to the SXI line of sight. The overall size of SXI is 9.5" in diameter x 30" long, the total weight of the telescope is about 16 kg, and the power budget is about 40 watts. Figure 1 shows the overall SXI assembly, while figure 2 is an exploded view showing all the major parts of the telescopes.

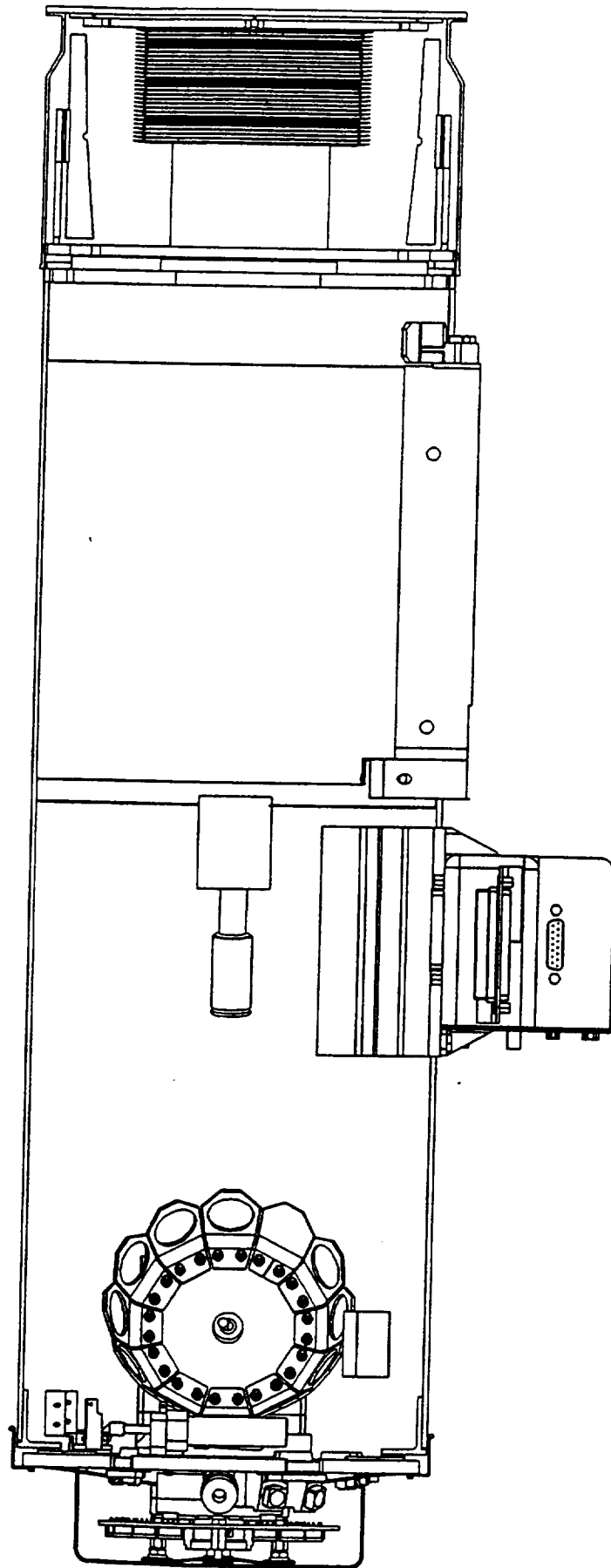
3.0 SXI MIRROR AND MOUNT

The CAO/UAH played a major role in the design and development of the mirror assembly for SXI. At the start of SXI program, the mirror assembly was designed to be installed to the optical bench by reaching through the graphite epoxy tube. The MSFC Optical branch and CAO were opposed to this concept because it posed serious risks to the mirror during installation. Moreover, if the mirror assembly had to be removed for some reason, it would have required disassembling the entire telescope. Therefore, CAO and MSFC jointly developed a design concept for a front-mounted mirror assembly to alleviate these problems. The design and development work performed by CAO for the mirror mount and the electroformed is briefly described in the following sections.

3.1 SXI NICKEL MIRROR

The flight mirror of SXI is made form zerodur and is mounted in a titanium mount, which is designed to provide differential thermal expansion over extreme temperatures encountered in space as shown in figure 3. The engineering model mirror manufactured by UTOS was not

Figure 1.
SOLAR XRAY IMAGER
TELESCOPE



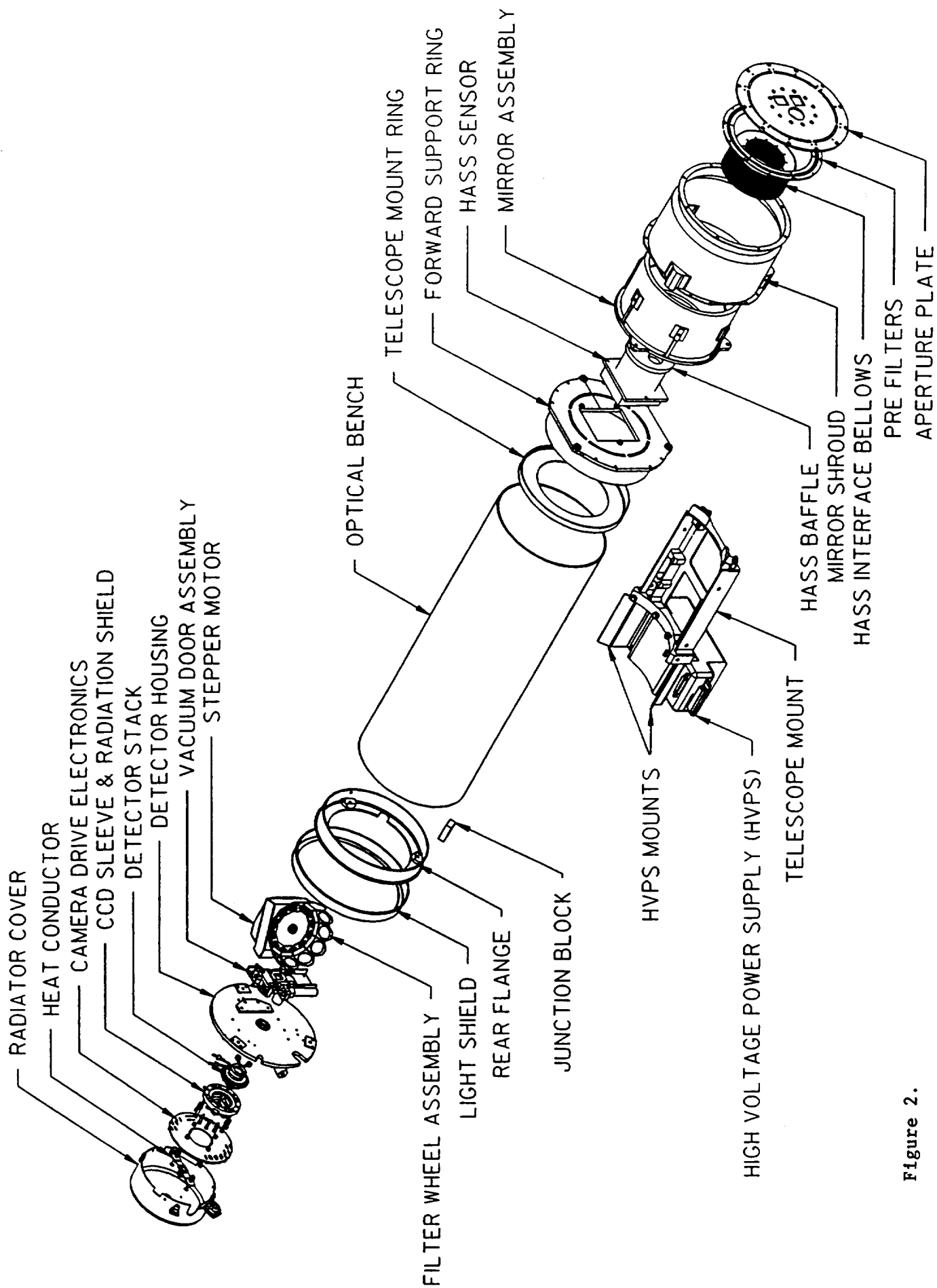


Figure 2.

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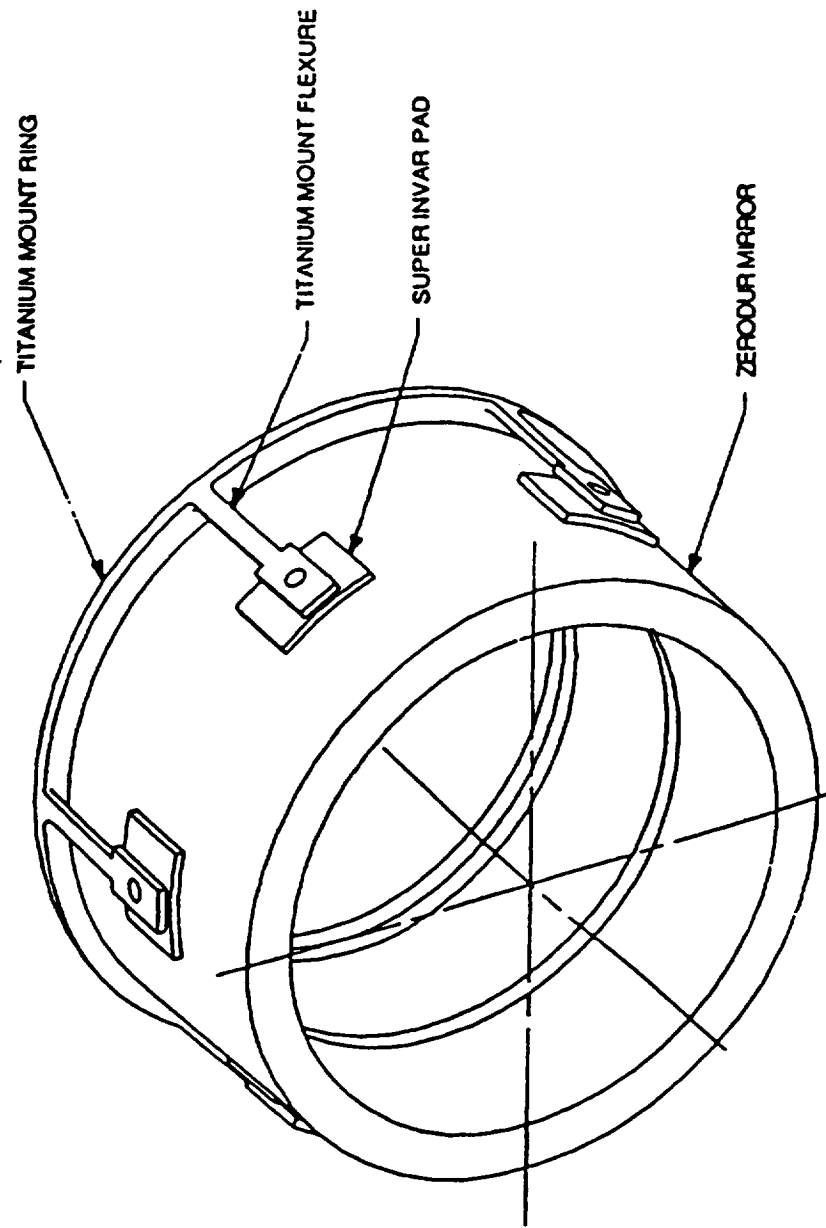
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SXI MIRROR ASSEMBLY

Figure 3.

scheduled to be fabricated until the end of 1994, and does not have the finished and coated optical surface. Therefore, MSFC asked CAO to fabricate a prototype nickel mirror, which could be used for preliminary assembly, alignment and testing of the engineering model telescope.

A prototype nickel mirror was designed and fabricated by UAH using the electro-forming process. A 3-piece mandrel, shown in figure 4, was designed and fabricated from aluminum for making this electroformed mirror. A number of other parts such as a rotator assembly and a fixture to diamond machine the mandrel were also designed and fabricated. The mandrel was diamond machined to match the parabolic/hyperbolic surfaces of the actual mirror. The 3-piece mandrel was then nickel plated, and polished to a surface finish of better than 20 Å. It was then cleaned and gold plated. Later on, the mirror with a wall thickness of about 1 mm was electroformed on this mandrel, and cryogenically separated from it. A picture of this gold plated nickel mirror is shown in figure 5. Initially, we were planning to precision machine a reference surface on the OD of the mirror to align it into its mount, but the mirror separated from its mandrel prematurely and the machining could not be performed.

3.2 SXI MIRROR MOUNT

The design of the prototype mirror mount is quite similar to the flight mirror mount being fabricated by UTOS. To minimize the cost of fabrication, a number of changes were made to simplify the design. The mirror mount has three ears, and it can be installed on the front flange with three shoulder screws from front of the telescope. The dowel pins have been eliminated, and a number of other changes were also made to accommodate the mounting of a thin nickel mirror instead of a thick zerodur mirror.

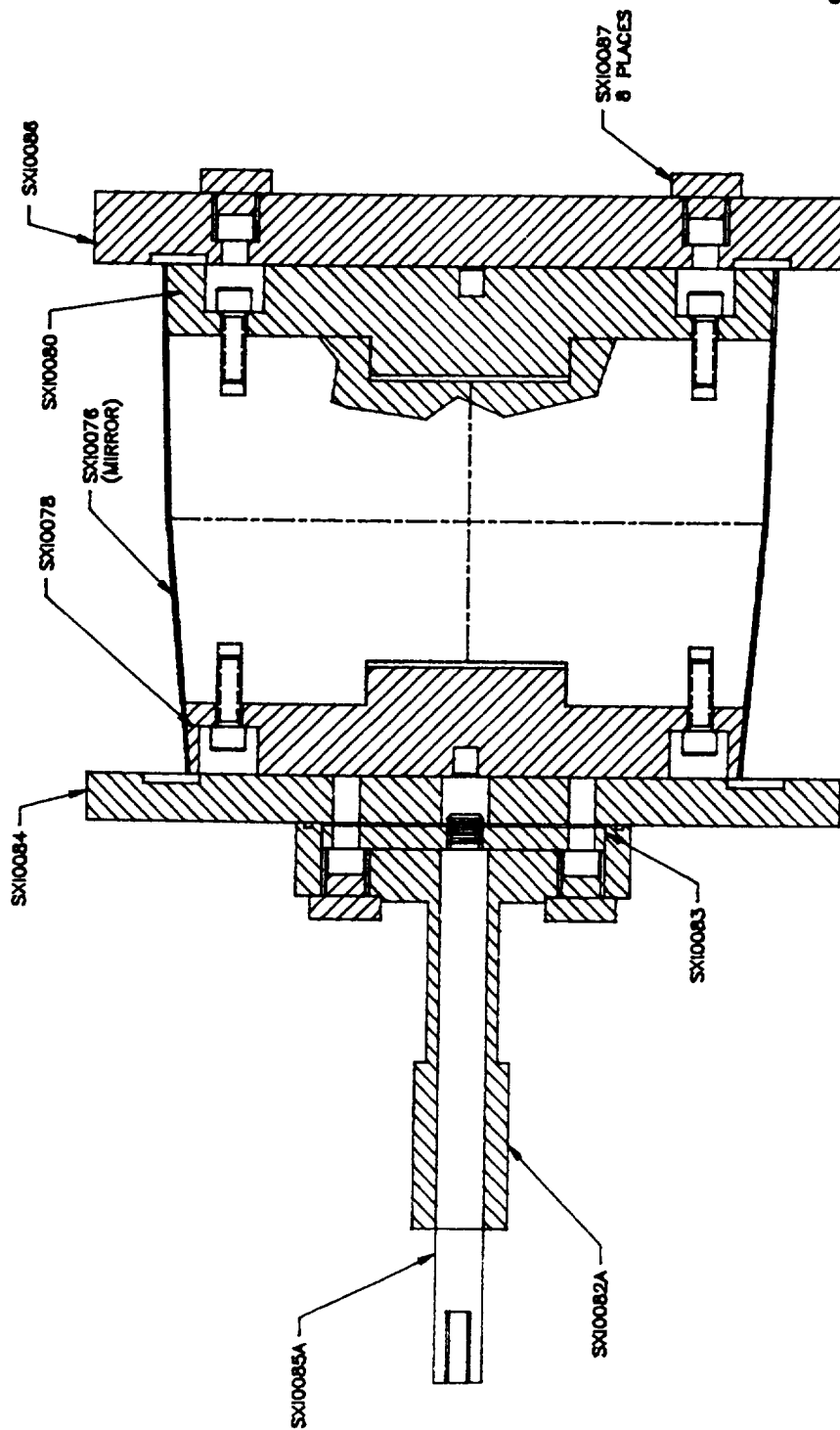
The mirror mount consists of a mounting flange, which interfaces with the forward support ring (FSR) of the telescope as shown in figure 6. Six fingers from this flange support a continuous ring for holding the mirror. The inside surface of this ring is machined conical to match the outer diameter of the mirror. The mirror mount was made from 316 CRES because its CTE matches the CTE of nickel very closely.

3.3 SXI PROTOTYPE MIRROR ASSEMBLY

A special fixture plate was designed and fabricated to support the mirror at a proper height in the mount for bonding. The plate was diamond machined to minimize the tilt of the assembled mirror relative to the interface pads on the mirror mount. The layout drawing (SXI 0092) showing the setup for mirror bonding is included in the appendix 3.

The electroformed prototype mirror was assembled in its mount using the fixture designed for this purpose. The mirror was placed on the diamond machined surface of the fixture sitting on a





MANDREL ASSEMBLY (PLATING) PROTOTYPE SXI MIRROR

SX1/SX11/SX10088.DWG
OCT. 16, 1993

Figure 4.

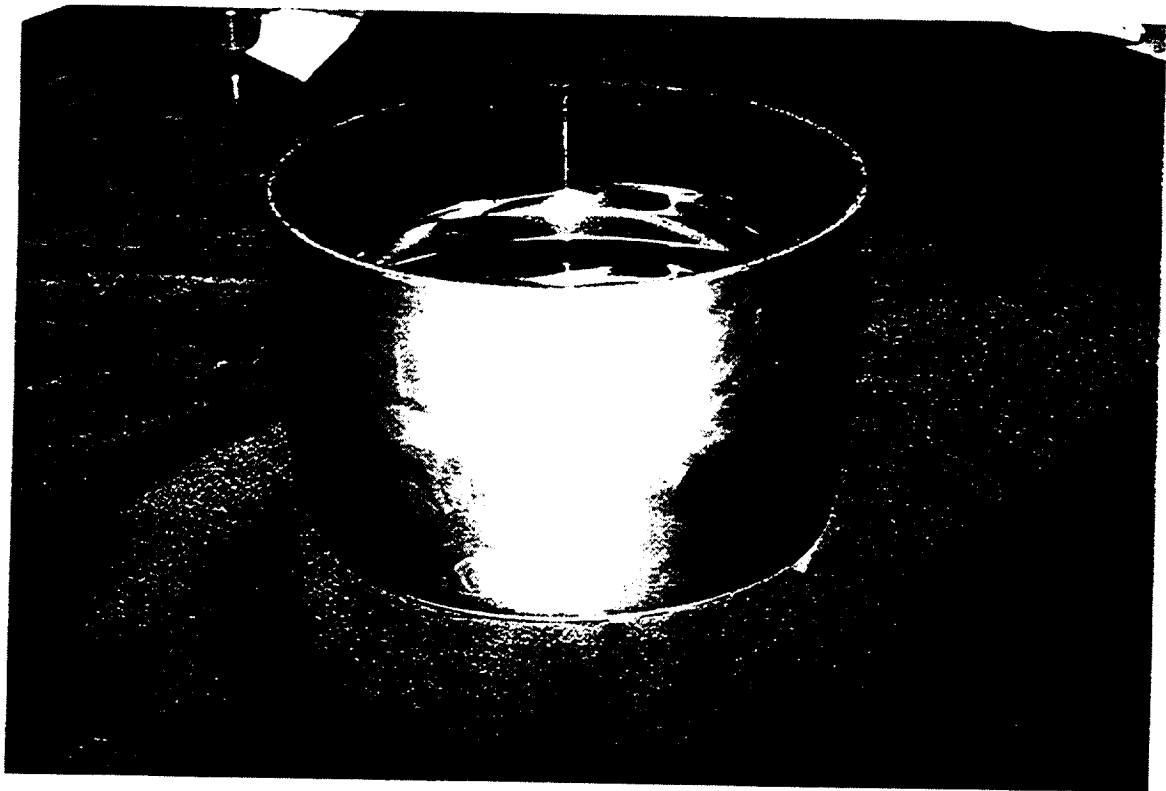


Figure 5. SXI Electroformed Nickel Mirror

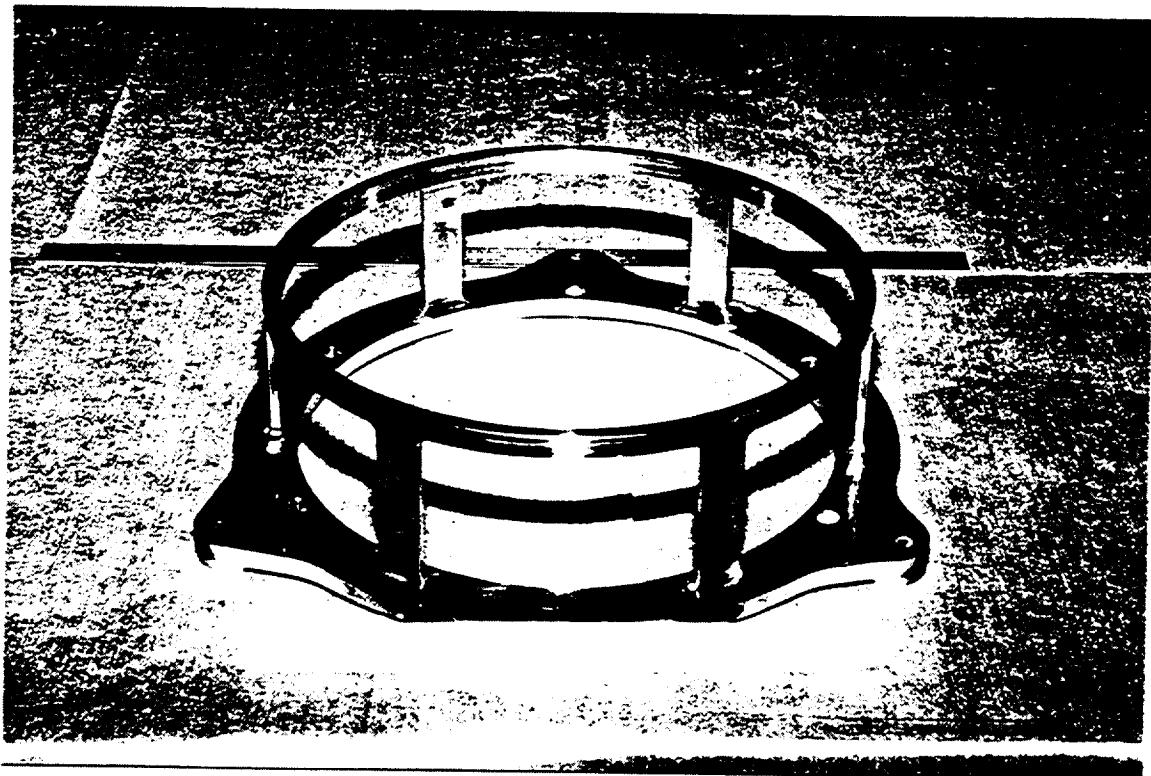


Figure 6. SXI Prototype Mirror Mount



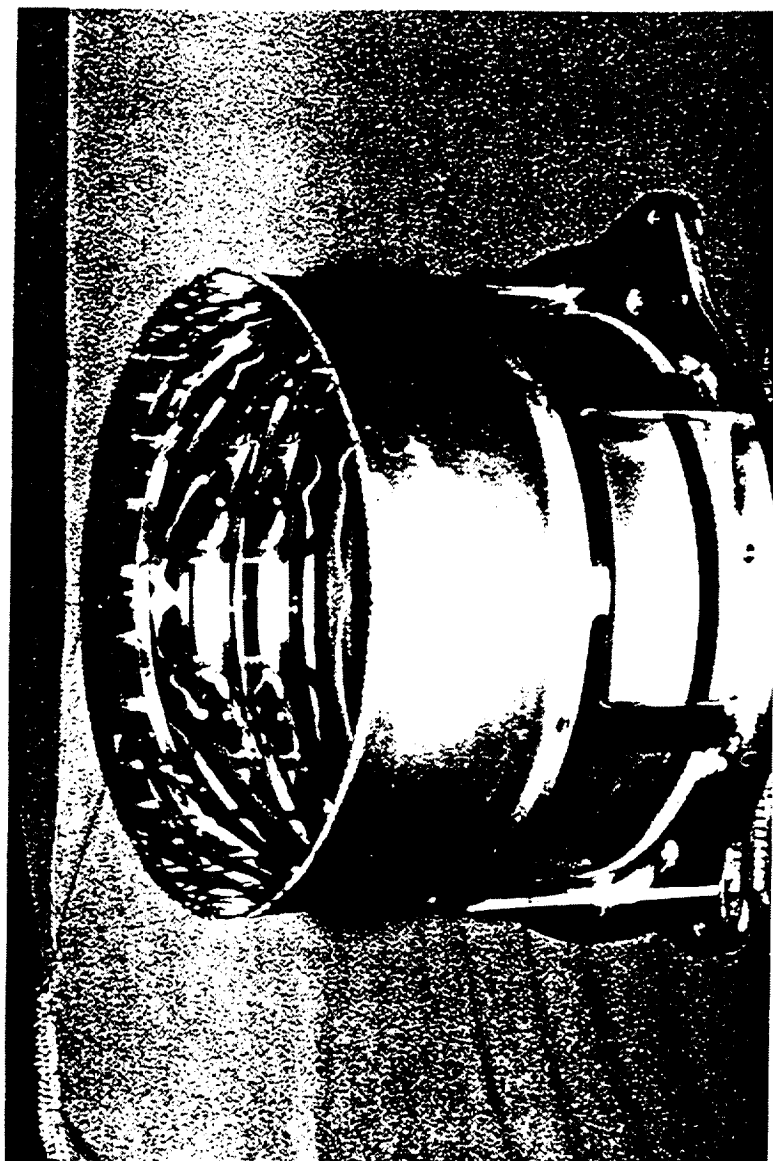


Figure 7. SXI Prototype Mirror Assembly

flat surface plate. The mirror mount was then positioned properly relative to the mirror. A suitable adhesive was used to bond the mirror to the mount at six locations around its circumference. The adhesive was allowed to cure at room temperature for 3 days. This completed mirror assembly, shown in figure 7, is now being integrated in the engineering model telescope.

4.0 SXI CAMERA ASSEMBLY

The CAO/UAH provided crucial technical support to MSFC in the coating and plating process development of a number of components of the SXI camera assembly. These components include the fiber optic taper (FOT) located between the micro-channel plate (MCP) and the CCD, the ceramic spacer between the MCP and the FOT, and contact ring and fingers. A very accurate process control was required to deposit the indium tin oxide (ITO) transparent conductive coating on the FOT to achieve a low enough resistance.

The ceramic spacer had be lapped flat and parallel before depositing a thick copper plating. The ceramic spacers for the camera assembly were coated (vacuum deposition) with chromium and copper to improve adhesion for a subsequent plating process. Then, a 0.0015" thick layer of copper was plated over the entire surface. These spacers were then lapped flat. Four of these ceramic insulators were photomasked and etched by Max Levy. These insulators rings were then gold plated and delivered to MSFC for assembly into the EM detector stack assembly.

The Be-Cu contact rings and finger for the camera assembly were also plated with the soft gold. The procedure for plating these parts for the flight assembly was also completed and submitted to MSFC.

A preliminary procedure for fabricating these parts for the flight model has been prepared. This preliminary procedure was discussed with SXI QA to identify the critical inspection steps during the fabrication. The detailed procedures for plating of the spacers, contact rings and fingers are described in appendix 3.

4.1 PHOSPHOR COATING OF FIBER OPTIC TAPER

The Chemical Engineering department of UAH was involved in identifying a suitable type of phosphor coating for the fiber optic tapers, and developing a procedure for applying this coating. The red phosphors coating evenly covers the FOT, and adheres to it in the form of a thin strong layer. A brief description of the work performed by them is as follows:

4.1.1 APPROACH

A coating was developed using polyvinyl acetate (PVA) and cellulose acetate. A number of different solvents were tested to dissolve PVA and cellulose acetate. Methyl ethyl ketone and ethyl acetate were the two solvents that dissolved PVA and cellulose acetate, and made a strong coating that did not flake or scratch off easily. This coating mixture was then mixed with the red phosphors for the purpose of covering and adhering to the FOT. The ratio of PVA or cellulose acetate to red phosphors was varied to obtain a stable coating that did not flake or scratch off easily. The red phosphors were filtered according to the particle size to obtain an evenly coated layer of phosphors. The phosphors were filtered using a syringe filtering system and a particle size distribution was obtained as shown in Figure 8. These coatings were reapplied using one particle size per coating.

4.1.2 SELECTING A COATING

Only the strongest PVA and cellulose acetate coatings were selected. The selected coatings adhered to the FOT easily and did not flake or powder off. The phosphors and coatings were first applied to glass slides at different concentrations to obtain the most stable coating. A coating of cellulose acetate with red phosphors was one coating that was strong and stable when applied to a glass slide. The same coating was applied to the FOT but was not as stable on its surface. As a result, this coating was not used on the FOT for the final coating. On the other hand, the PVA coatings adhered well to both the slides and FOT and was used on both of the FO tapers in the final coating. The composition of the two final coating were:

Coating the FOT with a # 19-221-12996:

1.52g Solution (made of 0.13g PVA and 2.69g ethyl acetate)
1.86g Red phosphors (size between 1 μ m-3 μ m)

Coating the second FOT:

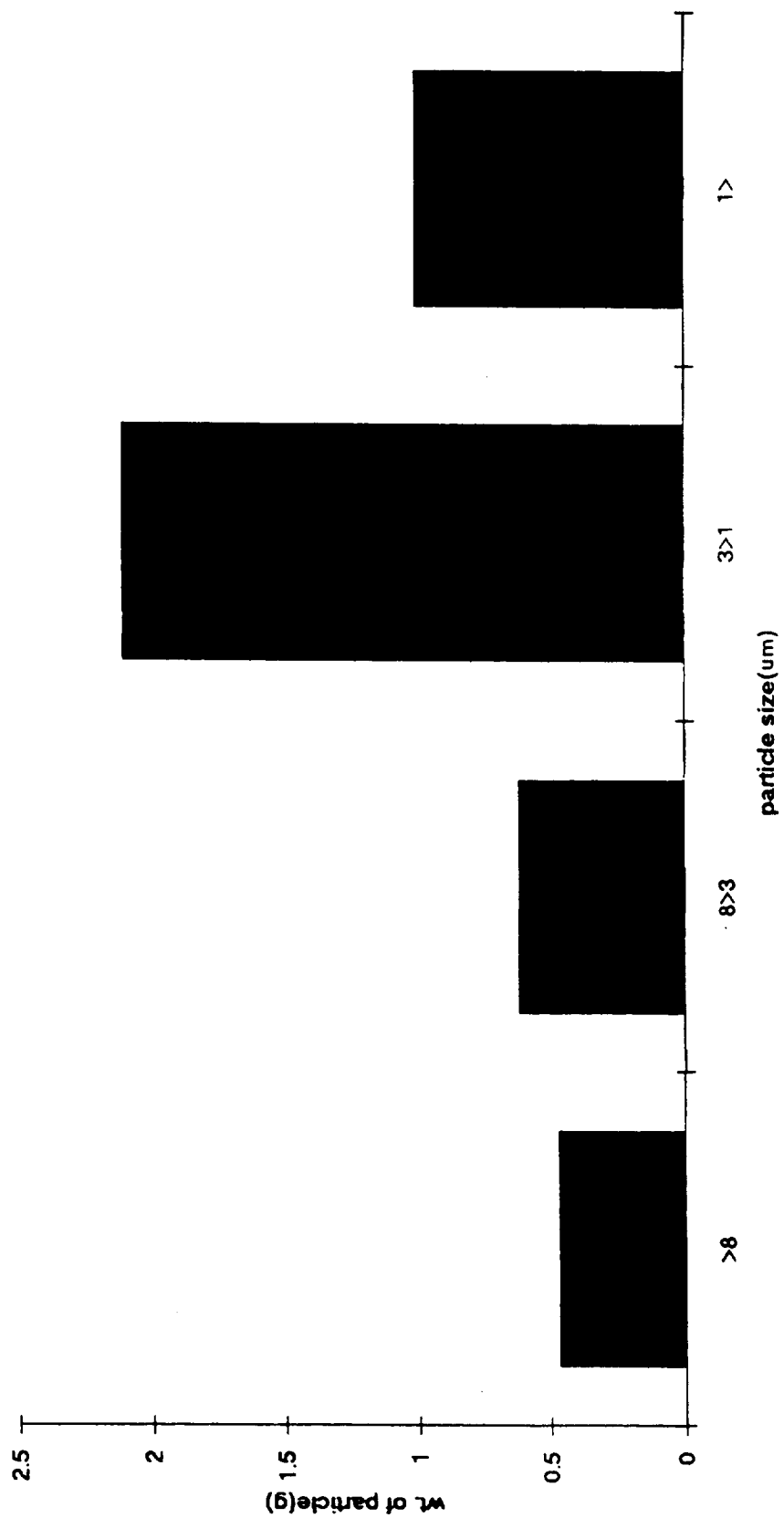
0.5g Solution (made of 0.7g PVA and 1.12g methyl ethyl ketone)
0.72g Red phosphors (size between 3 μ m-8 μ m)

4.1.3 APPLYING THE COATING

The first of the two coatings listed above was applied with the use of a machined ring designed to fit on the outer diameter of FOT. The ring made a raised wall of the desired film thickness at the top of the surface to be coated. The coating mixture was then applied to the FOT, and a flat edge was dragged across the top surface of the ring giving the desired coating thickness.

The latter of the two coatings was applied by an air brush method. A second machined part was designed to rest on the FOT around the outer edge of the coating surface. This allowed the

Figure 8.





coating to be applied to a smaller area on the FOT. The coating mixture was diluted with more solvent and air brushed onto the FOT, one layer at a time until a even coating covered the surface of FOT in a thin layer.

5. ASSEMBLY AND ALIGNMENT PLAN:

The SXI telescope has been designed with a minimum number of adjustments to achieve the desired alignment between the mirror assembly, HASS and the camera assembly. The optical bench consists of three major parts namely : the graphite epoxy tube, forward support ring (FSR) and the rear flange (RF). These parts need to be machined and assembled to a high accuracy to minimize the alignment steps during the assembly of the telescope. The only two adjustments available for alignment during the assembly are:

1. Three spacers between the RF and the focal plane assembly to adjust the focus for the finite and infinite x-ray sources, and for the UV collimator used for alignment. These spacers are designed for the adjustment of focus only, but may be used for tilt adjustment to account for any gross errors in the machining and assembly of optical bench parts.
2. The in-plane (x and y axes) fine adjustment of the CCD relative to the radiation shield. This adjustment is designed to align the centration and roll of the CCD due to the assembly errors in the camera assembly.

The CAO/UAH has developed a detailed high level assembly and alignment plan, which describes the sequence of assembly for the optical bench, and all the critical tolerances for major assemblies and how these tolerances must be verified to achieve a functional and aligned telescope. This assembly and alignment plan is attached as appendix 1.

6. CONCLUSION

The work performed by UAH in support of the SXI program has been described in this report. This research, design and development work was critical in resolving a number of technical issues relating to the development of engineering and flight model telescope. A number of critical prototype parts and procedures were developed and fabricated for the SXI mirror and camera assembly. UAH also provided technical support to the MSFC Optical Branch relating to the work being performed by other MSFC groups and UTOS by attending several quarterly reviews, PDR's and CDR's, and submitting the comments and recommendations in writing to improve the design and performance of critical SXI parts. A number of parts developed by UAH are being incorporated in the engineering model of the telescope. Later this year, some of the fabrication procedures developed by UAH will be used to fabricate the parts for the flight model telescope.

APPENDIX 1

**SXI ASSEMBLY
AND
ALIGNMENT PLAN**

MSFC-PLAN-2266

Solar X-Ray Imager (SXI)

ASSEMBLY AND ALIGNMENT PLAN

October 1994

SXI ASSEMBLY AND ALIGNMENT PLAN

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SXI ASSEMBLY AND ALIGNMENT PLAN

1.0 INTRODUCTION

The Solar X-ray Imager (SXI) is a telescope being designed to operate from orbit aboard a Geostationary Operational Environmental Satellite (GOES). Its mission is to monitor the X-ray spectrum of the sun and transmit video images to the earth in near real time. The precise alignment of the optical elements, accurate records of any misalignments-alignments and the stability of these elements over the mission lifetime is critical to the image quality.

The purpose of this document is to define a plan for assembling aligning all the critical optical elements of the telescope, calibrating the inevitable misalignments-alignments, and specifying the boundary of change that can be expected during the launch and in the temperature extremes of space. Based on this concept a more detailed assembly procedure will follow, which will describe the assembly procedures and alignment techniques at a subassembly level, and the calibration and inspection equipment to be used in this task.

1.1 THE SXI TELESCOPE

The primary elements of the SXI telescope are the mirror assembly, the High Accuracy Sun Sensor (HASS), and the focal plane detector assembly. These elements are assembled to a graphite-cyanate ester cylinder, which serves as an optical bench and thermal / environmental shield. The optical bench provides a mechanical interface to the GOES spacecraft through a telescope mount. This bracket mounts to the Instrument Mounting Panel (IMP), located inside the X-ray Positioner (XRP) on the solar array yoke of the GOES, thereby providing a continuous solar pointing for the SXI.

2.0 COORDINATES AND CONVENTIONS

Figure 1 identifies the Solar / Equatorial Reference axes [E], the frame of interest to the user, the frame from which the experiment is conducted. It is an orbit referenced, solar oriented system whose X-axis lies in the orbit plane, inclined to the sun-line through an angle, beta (β). The Y-axis is positive toward orbital north, and for this equatorial orbit, towards the polar north.

Figure 2 shows the coordinate relationship between [E], the GOES yoke, and the SXI body axes [B]. In normal operational mode, [B] will be aligned in space as follows: the X-axis will be on the sun line; the Y-axis will be in the southern hemisphere; and, the Z-axis will lie in the orbital plane. The solar array drive axis will be ideally aligned with orbital north, and the beta drive axis will lie in the orbit plane.

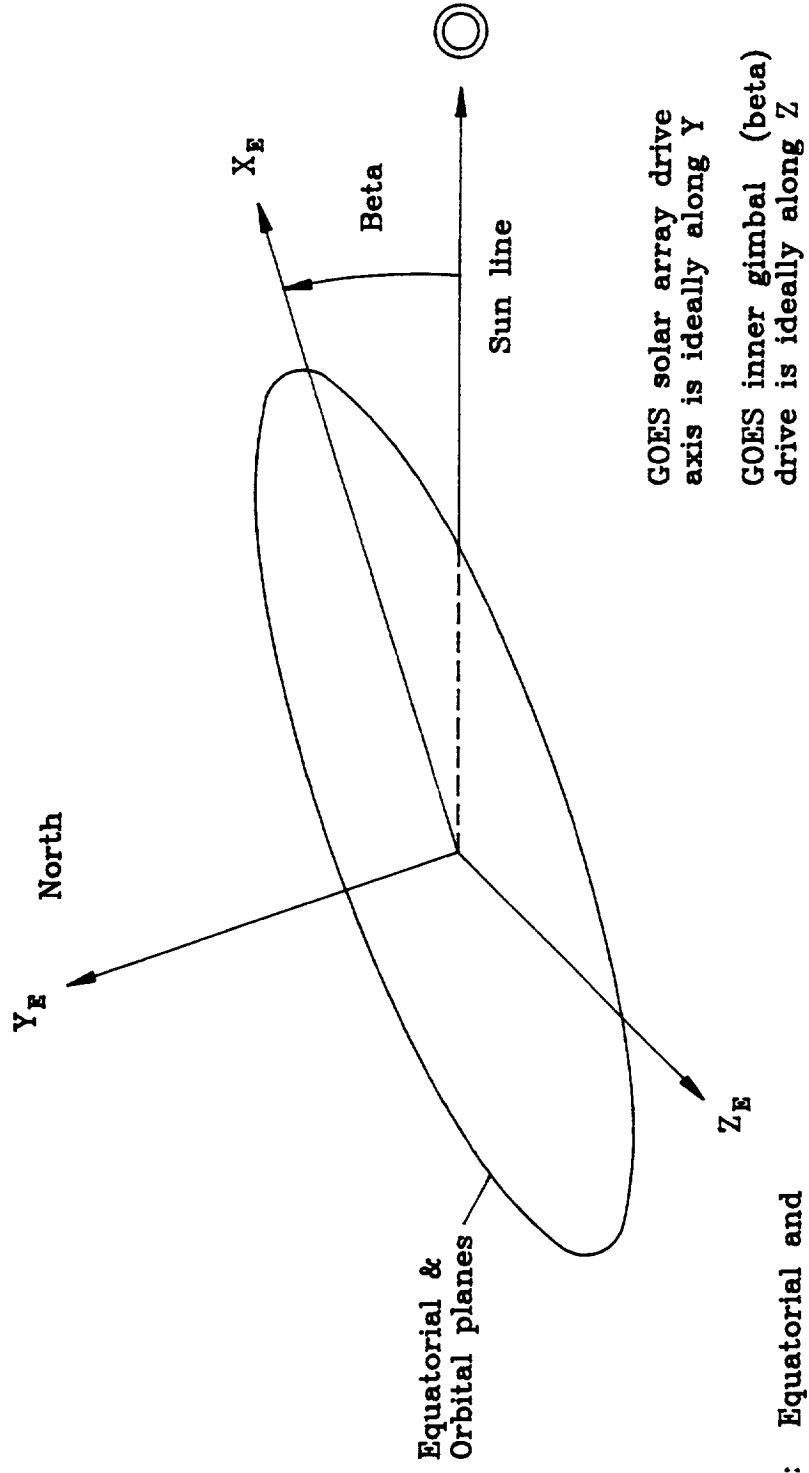
Figure 3 introduces the optical coordinate system [O] and relates it to [B]. The origin of this frame is at the focal point of the mirror, with X_O through the mirror center-line. The Y_O and Z_O axes are aligned parallel to the columns and rows of pixels on the CCD.

The SXI alignment involves the identification, translation, and measurement of the relative misalignments between the various coordinate systems. The alignment procedure for SXI will involve the following steps:

- (1) identify a mirror optical axis alignment reference $X_{O(ref)}$
- (2) measure the $X_{O(ref)}$ with respect to mirror optical axis X_O
- (3) assemble HASS and quantify the misalignment between HASS and mirror optical axis X_O
- (4) align and position the focal plane assembly to X_O
- (5) center the CCD detector to X_O and Y_O

The alignment of the SXI telescope to the GOES and the pointing of the SXI by the spacecraft is not included as part of this plan.

Solar / Equatorial Reference axes



Note: Equatorial and orbital planes are ideally aligned in GOES orbit.

Figure 1

GOES / SXI BODY AXES ALIGNMENT

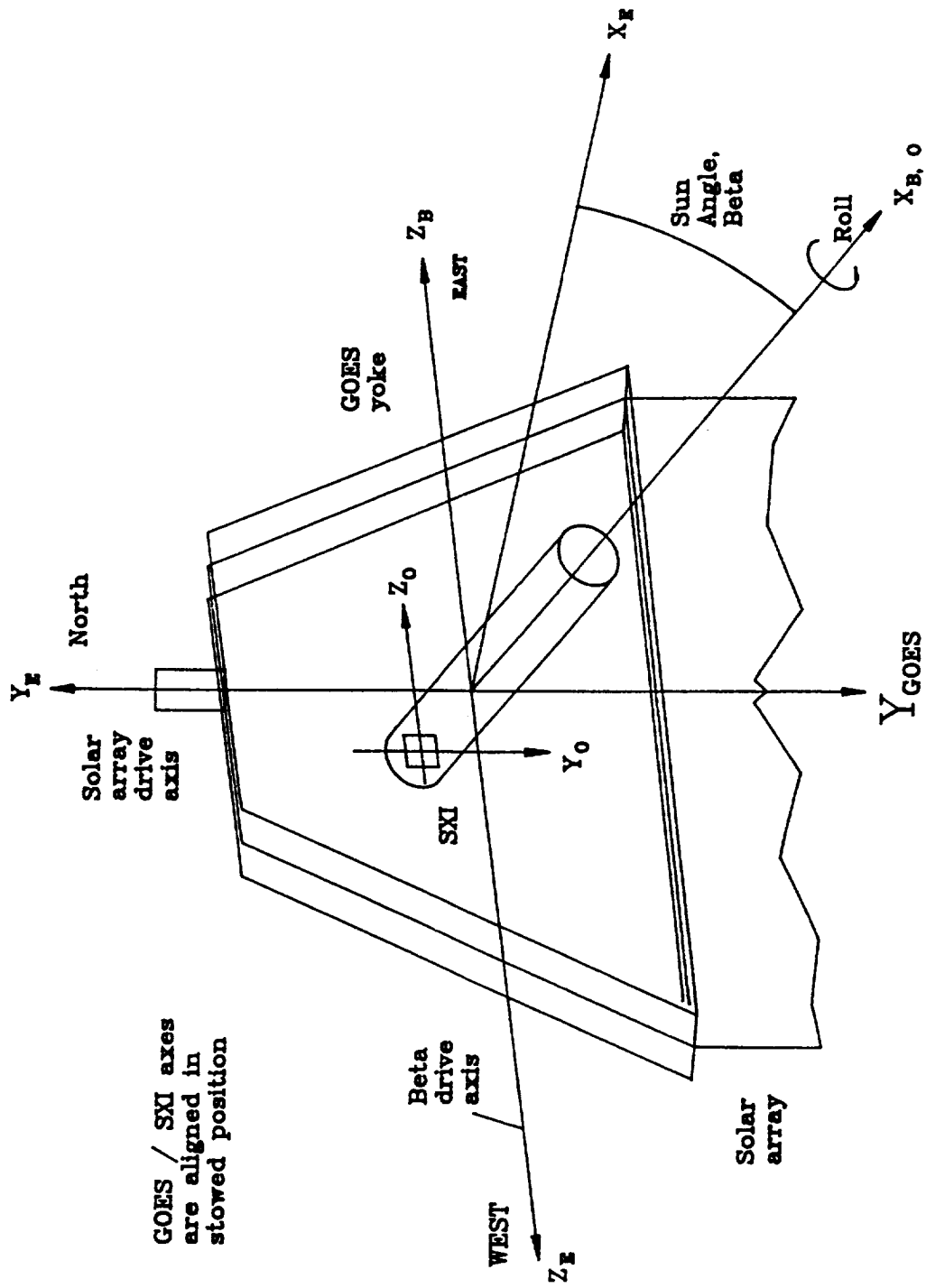


Figure 2

SXI BODY / OPTICAL AXES

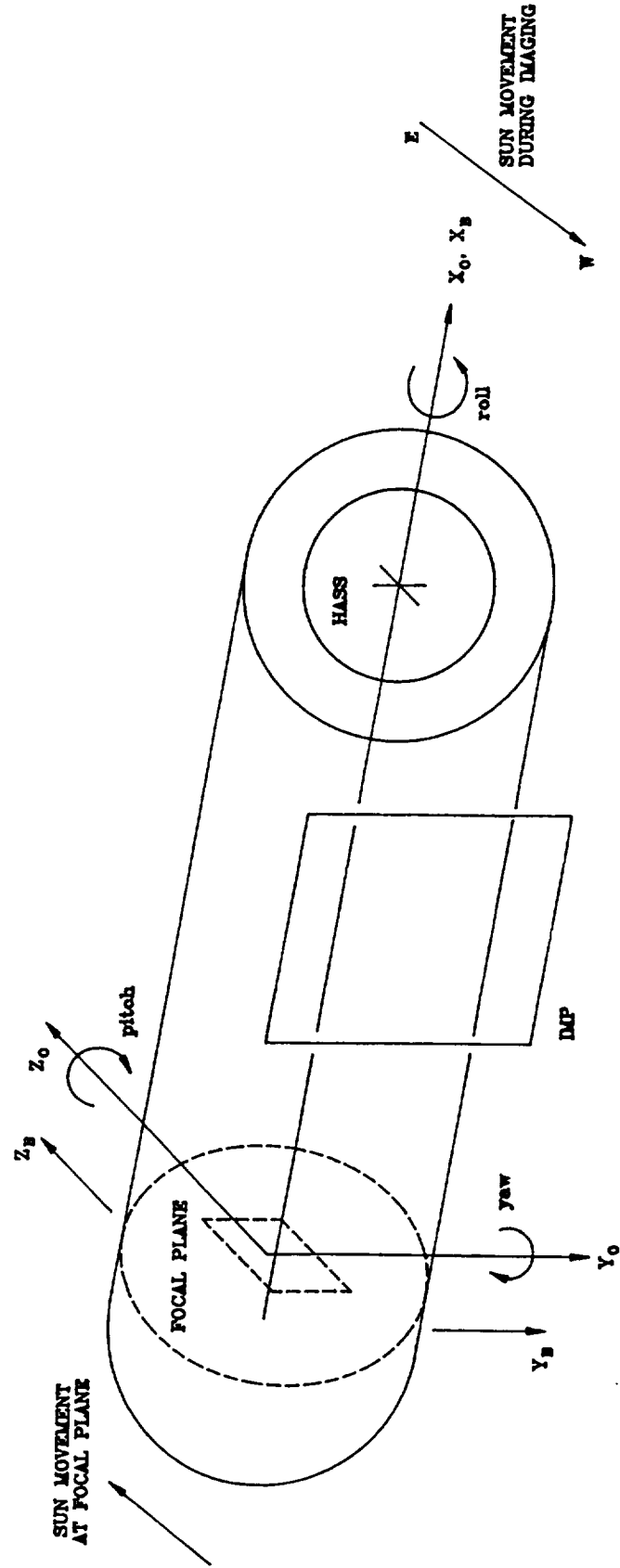


Figure 3

3.0 SXI OPTICAL AND SENSING ELEMENTS

The basic coordinate systems are determined by the optical elements of SXI and the gimbal geometry to the GOES experiment platform. They relate the sensing elements of the SXI to the solar target, and their alignments are critical for the pointing accuracy. The following sections give brief technical description of these elements, how their alignment is determined, and why they are contributors to the alignment error.

3.1 Mirror Assembly

The mirror assembly of the SXI consists of a paraboloid and a hyperboloid mirrors in a two-mirror grazing incidence configuration. The design consists of a single Zerodur mirror element with both optical surfaces fabricated integrally, six SUPER INVAR pads bonded to the mirror element, and a titanium mounting ring consisting of six support fingers that are bonded to the SUPER INVAR pads.

An integral part of the mirror assembly is an alignment reference mirror $X_{O(ref)}$ on the leading edge of the main mirror. This alignment reference is optically flat to within one quarter of a wavelength. The area of the reference mirror is over five (5) cm^2 and it is suitable for autocollimation purposes.

The mirror assembly mounting ring provides a 3-point structural interface with the Forward Support Ring (FSR) bonded into the optical bench of the telescope. The three precision machined interface pads on the mirror mount are coplanar, and orthogonal to the axis of the mirror within **10** arc seconds.

The location of the optical axis of the mirror assembly falls within a circle of radius **0.0127** cm, as defined by the attachment pads of the mounting ring. The location shall be measured to within **± 0.0025** cm.

3.2 HASS Assembly

An alignment mirror is provided to permit boresighting of the HASS optical axis. The normal to the alignment mirror is parallel to the HASS optical axis to within **1**

arc minute. The alignment knowledge of the HASS reference with respect to the sensor's optical axis is better than 5 arc seconds.

The HASS is mounted via a three-point mounting system. The axis of HASS is electronically calibrated to be orthogonal to within 5 arc seconds of the plane defined the 3 mounting points. The sun angle shall be sensed with respect to the orthogonal Y_0 and Z_0 axes with an accuracy of 1 arc minute.

3.3 Focal Plane Detector Assembly

The focal plane assembly components are: 1) a camera assembly, and 2) a structural element that serves as housing for the detector.

The camera assembly is the major element and is an integral part of the focal plane assembly. The active elements of the camera assembly consist of an electro-optical imaging system (detector stack), drive electronics (located on a head board), and timing and video amplifier circuitry (located in the high voltage power supply). The stack includes a grid, the Micro-channel Plate (MCP), a phosphor coated Fiber Optic Taper (FOT) and the Charged Coupled Device (CCD), all located along the optical axis near the focal plane.

The housing provides for the mounting of the MCP, and fiber optic coupler/CCD array, radiation shield and head board. The camera housing will provide the main structural interface with the optical bench of the telescope. The interface is a 3-pad mount. The interface pads on the housing are lapped flat and coplanar to 0.0002" tolerance.

4.0 TELESCOPE ALIGNMENT REQUIREMENTS

The key factors that define the SXI telescope alignment requirements are: the telescope performance (resolution, image blur and smear), pointing knowledge, and co-alignment with GOES. The following are SXI alignment requirements.

4.1 Mirror Assembly/HASS Co-alignment

The alignment of optical axis of the HASS shall be checked to the mirror optical axis to be within ± 2.0 arc-min.

4.2 Optical Axis Perpendicularly

The optical axis shall be perpendicular to the focal plane detector to within **60** arc-seconds. The perpendicularity of the optical axis to the plane defined by the three (3) interface pads of the mirror mounting ring shall be within **10** arc-seconds.

4.3 Image Centering

The instrument shall maintain the optical axis centered on the focal plane detector to within ± 10 arc-sec.

4.4 Field of View Alignment

One dimension of the field of view shall be aligned with the interface plate to within ± 0.2 degrees.

5.0 ASSEMBLY CONFIGURATION AND REFERENCES

5.1 Alignment Configuration

The optical bench assembly consists of a composite cylinder, forward support ring (FSR) and rear flange (RF). The optical bench assembly provides a lightweight and stable mounting structure for the mirror, HASS and focal plane assemblies.

The forward support ring and the rear flange are bonded into the forward and rear ends of the optical bench to provide the mounting interfaces between optical bench and the mirror / HASS and focal plane assemblies. The interface at FSR is through three precision raised pads. The parallelism (relative tilt between the forward support ring and rear flange) and the axial separation between the mounting surfaces will be measured to an accuracy **5** microns (0.0002") utilizing a three-axis coordinate measuring machine (CMM). It should be noted that axial change in length of the optical bench due to moisture absorption and temperature changes must be determined to within the required tolerances. This data will be utilized in alignment steps described below. Compensation will be made to the axial length data for the effects of moisture absorption by the optical bench.

The mirror assembly and HASS are attached to the forward support ring at the front end of the optical bench. The camera housing is bolted to the rear flange via focusing spacers.

Alignment of the SXI telescope to the GOES will be achieved using the HASS alignment reference mirror. This alignment is the responsibility of SS/L and is not included as part of this plan..

5.2 Alignment References

The observation of the camera output and two optical reference mirrors will be utilized in the telescope alignment process.

The two optical reference mirrors will be utilized in the pointing alignment of the Mirror Assembly to the HASS . These reference mirrors are defined as:

- 1) the mirror optical axis reference mirror ($X_{O(ref)}$). The normal to this alignment mirror will be parallel to the mirror optical axis to within **10** arc-seconds, and known to within **±2** arc seconds.

2) the HASS reference mirror ($X_{O(HASS\ ref)}$). The normal to the alignment mirror shall be parallel to the HASS optical axis to within **1** arc minute and known to within **5** arc seconds.

6.0 SXI ASSEMBLY AND ALIGNMENT PLAN

The SXI telescope has been designed with a minimum number of adjustments to achieve the desired alignment between the mirror assembly, HASS and the camera assembly. The optical bench parts (tube, FSR and RF) will be machined and assembled to a high accuracy to minimize the alignment steps during the assembly of the telescope. The only two adjustments available for alignment during the assembly are:

1. Three spacers between the RF and the focal plane assembly to adjust the focus for the finite and infinite x-ray sources, and for the UV collimator used for alignment. These spacers are designed for the adjustment of focus only, but may be used for tilt adjustment to account for any gross errors in the machining and assembly of optical bench parts.
2. The in-plane (x and y axes) fine adjustment of the CCD relative to the radiation shield. This adjustment is designed to align the centration and roll of the CCD due to the assembly errors in the camera assembly.

6.1 Optical Bench Assembly

6.1.1 Telescope Mount

Bond the telescope mount (TM) to the optical bench using the precision assembly fixture such that the telescope mounting plane is orthogonal to the forward support ring to within **0.010"**.

6.1.2 Forward Support Ring (FSR) and Rear Flange Assembly

Assemble the FSR and rear flange in the optical bench by using the same fixture. The two flanges must be located relative to each other to better than **0.005"** axially, and must be parallel to each other within **5 arc seconds (0.0002" over 7.63" dia)**, and be rotationally aligned to within **0.2 deg.**

Inspect the optical bench assembly on the Zeiss coordinate measuring machine (CMM), which has a resolution of 0.1 micron, and an accuracy of better than 2 microns. The following critical assembly tolerances shall be inspected and verified:

Flatness of FSR and RF:	< 0.0002"
Parallelism between FSR and RF:	< 5 arc sec.
Rel. rotation between FSR and RF:	< 0.2 deg.
Perpendicularity of TM rel. FSR:	<0.010"

Also measure the actual length of the optical bench between the FSR and RF interfaces to an accuracy of 0.0001" (2.5 microns). The effects of moisture and temperature on the length of the tube shall also be accounted for.

6.2 HASS and Mirror Assembly to Optical Bench

6.2.1 HASS to Forward Support Ring (FSR)

The reference mirror on the HASS is orthogonal to the HASS optical axis to within **1 arc min** and known to within **5 arc seconds**. The HASS has three pads that interface with the three pads on the forward support ring (FSR). The HASS optical axis is electronically calibrated to be perpendicular to the plane of these pads to within **5 arc seconds**. The set of three HAAS mounting pads on FSR is machined flat and coplanar to within **0.0002"** relative to the mirror mounting pads on FSR, yielding a tilt error of less than **5 arc seconds**. Therefore, the maximum cumulative tilt error between the HASS optical axis and the FSR will be **10 arc seconds**.

The roll alignment of the HASS relative to the telescope mount is controlled by the clearance between the screws and the mounting holes in the HASS, and the location tolerance of the threaded hole on FSR. The maximum tilt error due to this clearance can be 12 arc min (0.010" clearance over 2.800" center to center distance).

Assemble the HASS to FSR using appropriate hardware. The tilt alignment of HASS will be checked relative to the mirror optical axis after the next assembly step.

6.2.2 Mirror to Forward Support Ring (FSR)

The maximum tilt error between the mirror optical axis and it's mount is **10** arc seconds. As the maximum tilt error between the FSR and rear flange (RF) is **5** arc sec, therefore, mirror optical axis will be orthogonal to the rear flange within **15** arc sec. Assemble the mirror assembly to the FSR using appropriate hardware.

6.2.2.1 Mirror to HASS

The maximum tilt error between the mirror optical axis and its mount is **10** arc seconds. Therefore, the maximum tilt error between the mirror optical axis and the HASS optical axis will be **20** arc seconds. Use a visible-light autocollimator (VLAC) to verify this assembly tolerance by autocollimating off of the edge reference mirror (ERM) and the reference mirror on the HASS.

6.3 Focal Plane Assembly to Rear Flange

An optical alignment and test station has been designed to align the focal plane assembly relative to the SXI mirror. This alignment setup includes a UV collimator (UVC), a visible light autocollimator (VLAC) , a reference flat, an alignment microscope and a multi-axis tilt stage to support the telescope. The tilt stage has a total travel of +/- 1.0 degree, and a resolution of 1 arc second.

Initially, the UVC, VLAC and reference flats are aligned to each other such that the collimated beam from the UVC is orthogonal to the reference flat. The SXI telescope is then mounted on the tilt stage and it is adjusted such that the ERM is orthogonal to the collimated UV beam. This alignment will be verified by the alignment microscope. Also, use the VLAC to check the tilt of HASS reference mirror at this stage. Next, proceed to verify the focus and tilt alignment of focal plane (these can not be adjusted), and to adjust the centration and roll of the CCD.

6.3.1 Focus Adjustment:

The required thickness of the focus spacers to position the camera assembly at the proper focal length will be determined by the following metrology and analytical calculations:

The actual mirror focal length number supplied by UTOS, i.e. the distance between the mirror mount pads and the focal point of the mirror.

The actual measured length of the optical bench., i.e. the distance between the mounting surfaces on the FSR and RF. The effects of moisture absorption and temperature on the length of optical bench will also be taken into account.

The calculated distance between the MCP and the camera housing mounting pads based on the actual measurements of the parts. This metrology will include the distance between the FOT face to the mounting flange, the thickness of ceramic insulator and the distance between the camera housing mounting pads and the mounting surface of the FOT flange. All these dimensions will be measured to an accuracy of 1-2 microns.

The optical effects of the sapphire window for the UV collimator.

Based on these numbers, the required thickness of the spacers will be calculated, and a set 3 spacers will be machined to this nominal thickness. Four

more sets of the spacers will also be machined with +/- 10 and 20 micron variation from the nominal thickness.

The camera assembly will be assembled to RF using the 3 spacers and appropriate hardware. The focus of the telescope will be verified by making sure that the collimated beam of UVC focuses to the desired spot size on the CCD. This desired spot size will be determined from the metrology of the mirror and detector, and the analytical optical performance predictions.

6.3.2 Tilt Alignment

The machining and assembly tolerances of the camera housing and the detector stack shall ensure that the MCP is parallel to the camera housing mounting pads to within **20** arc seconds. The three focusing spacers can be lapped or diamond machined flat and parallel to within a tolerance of 0.0002", producing a tilt error of less than **5** arc sec. The total tilt error between the mirror optical axis and the rear flange is less than **15** arc sec. Therefore, the maximum **cumulative** (RSS) tilt error between the mirror optical axis and the MCP face will be less than **25** arc seconds, which is well within the **60** arc-sec tilt requirement.

Use the UV collimator (UVC) to verify the tilt tolerance by tilting the telescope such that the UVC focused beam spot scans across the rows and columns of pixels on the CCD. For an acceptable tilt of the focal plane, the spot size of the beam must stay constant within one pixel, i.e. the spot diameter must stay within the desired size on the CCD. This desired spot size will be determined from the metrology of the mirror and detector, and the analytical optical performance predictions.

If the focus of telescope and tilt of the focal plane check out to be within the acceptable limits, then proceed to align the centration and roll of the CCD. Otherwise, disassemble the camera housing from the RF and adjust the thickness of spacers to correct for the focus and/or tilt errors.

6.3.3 Centering Alignment:

Alignment capability between the CCD and the radiation shield will be utilized to center the CCD within ± 7.5 arc-sec with respect to the mirror optical axis, and to rotate the CCD with respect to the telescope mounting plane.

The centering of the CCD will be achieved by observing the centroid of the focused spot of the UV collimated beam on the CCD. The CCD will be adjusted in Y and Z axes (in-plane) until the focused beam is centered within the central 3×3 pixel square on the CCD.

6.3.4 Roll Alignment:

The roll alignment of the CCD will be checked by scanning the UVC focused beam spot on the CCD in a straight line by pivoting the telescope. The CCD will be rotated relative to the radiation shield to ensure that the UVC beam spot scans across the CCD within the same 2 row and 2 columns of pixels to meet the roll requirement of 0.2 degrees (CCD relative to telescope mount).

After completing the alignment of the CCD, bond it to the radiation shield to retain its alignment.

7.0 FLIGHT SPACER INSTALLATION

Following the successful X-ray testing and calibration, the finite source spacers will be replaced by the infinite source spacers. The thickness shall be calculated using the finite source data. Then, close tolerance pins will be inserted through the detector housing into the rear flange to maintain the alignment and to provide repeatability.

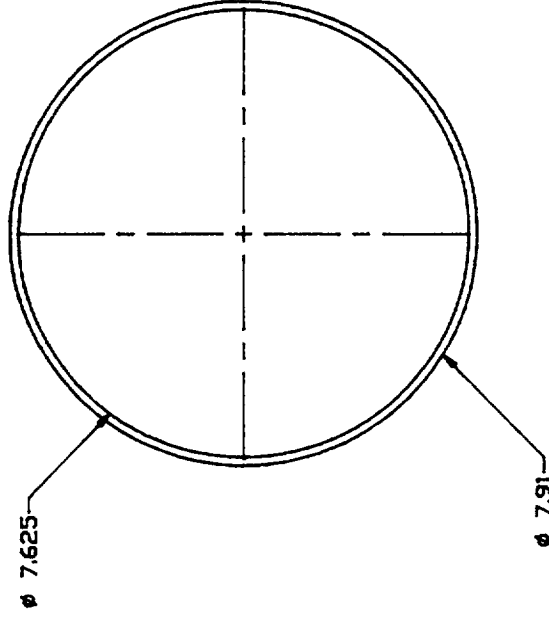
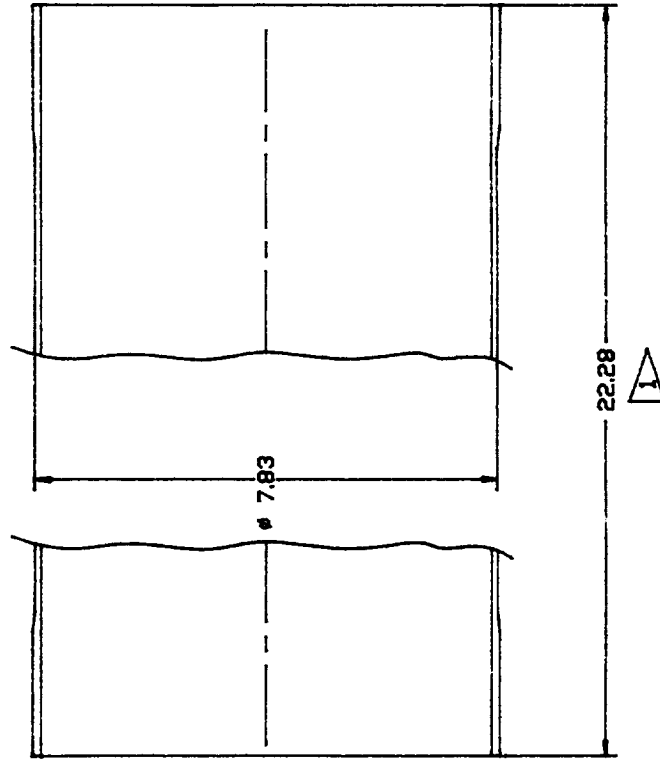


APPENDIX 2

SXI DRAWINGS

NOTES:

1 ALL NOTES AND DIMENSIONS OF
DRAWINGS, SX10001-3.DWG APPLY
EXCEPT FOR THE OVERALL LENGTH.



SX10062

PRELIMINARY



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Huntsville, AL 35894

GRAPHITE EPIDXY
OPTICAL BENCH
(SX1 PROTOTYPE)

SX10062

1

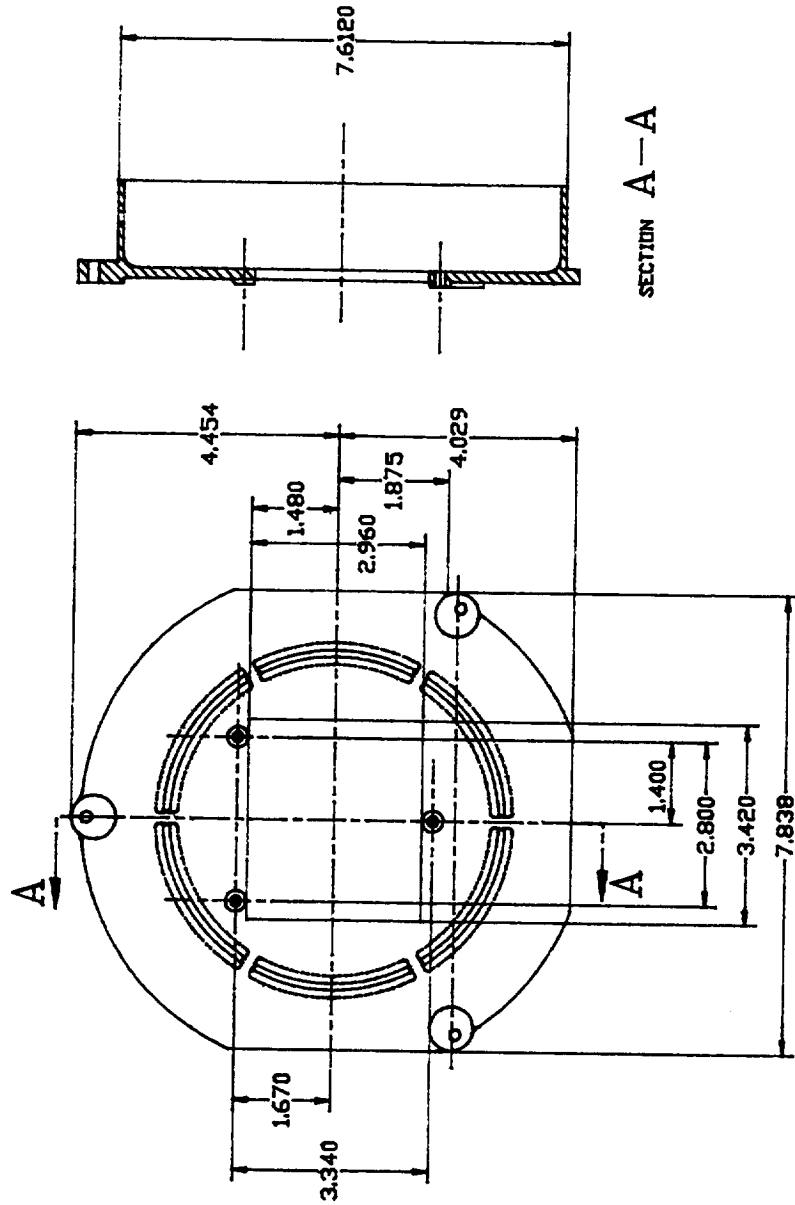
A
 B
 C
 D

REVISED FOR NEW DESIGN
 19700 000 000 000
 19700 000 000 000
 19700 000 000 000
 19700 000 000 000

00000 AA
 00000 AA
 00000
 00000

NOTES:

1. MATERIAL: CRES 300 SERIES
(CRES 310 OR 316 PREFERRED)
2. REMOVE ALL BURRS AND BREAK
SHARP EDGES.
3. 125° ALL MACHINED SURFACES
UNLESS OTHERWISE SPECIFIED.
4. ALL FILLET RADII ARE TO BE
.03 MAX. UNLESS OTHERWISE
SPECIFIED.
5. DATUM -A- IS A PLANE DEFINED
BY ALL 8 PADS.
6. PINS MAY BE INSTALLED
AFTER ASSEMBLY IN SX10070.



SECTION A-A

SX10063
 D

FRONT FLANGE
 (PROTOTYPE)

SX10063
 1


SX10063E

◀ ▶ ↻

NOTES:

△ MATERIAL: CRES 300 SERIES
(CRES 310 OR 316 PREFERRED).

2. REMOVE ALL BURRS AND BREAK SHARP EDGES.
3. 125 / ALL MACHINED SURFACES UNLESS OTHERWISE SPECIFIED.
4. ALL FILLET RADII ARE TO BE .03 MAX. UNLESS OTHERWISE SPECIFIED.

5  DATUM -A- IS A PLANE DEFINED BY ALL 3 PADS.

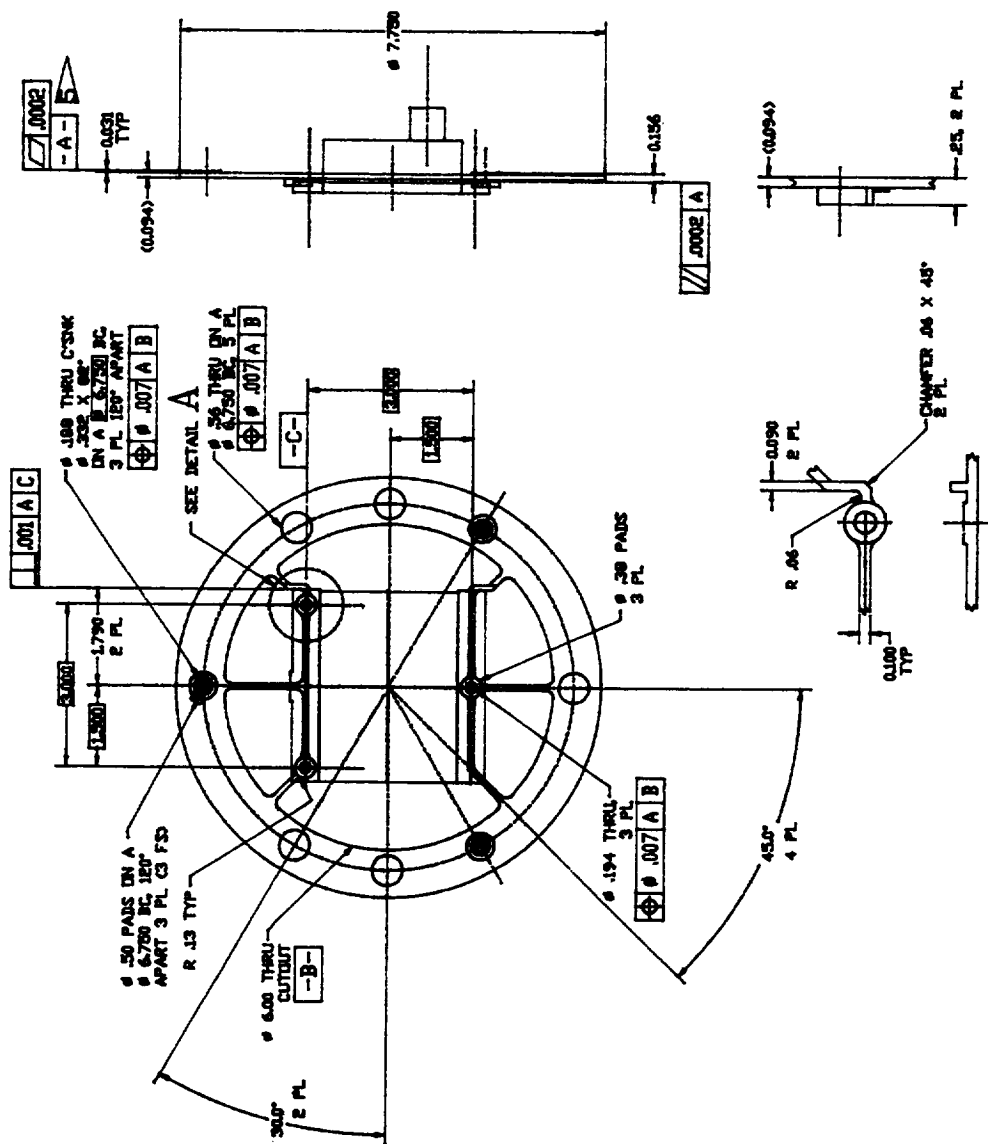
3
SX10064



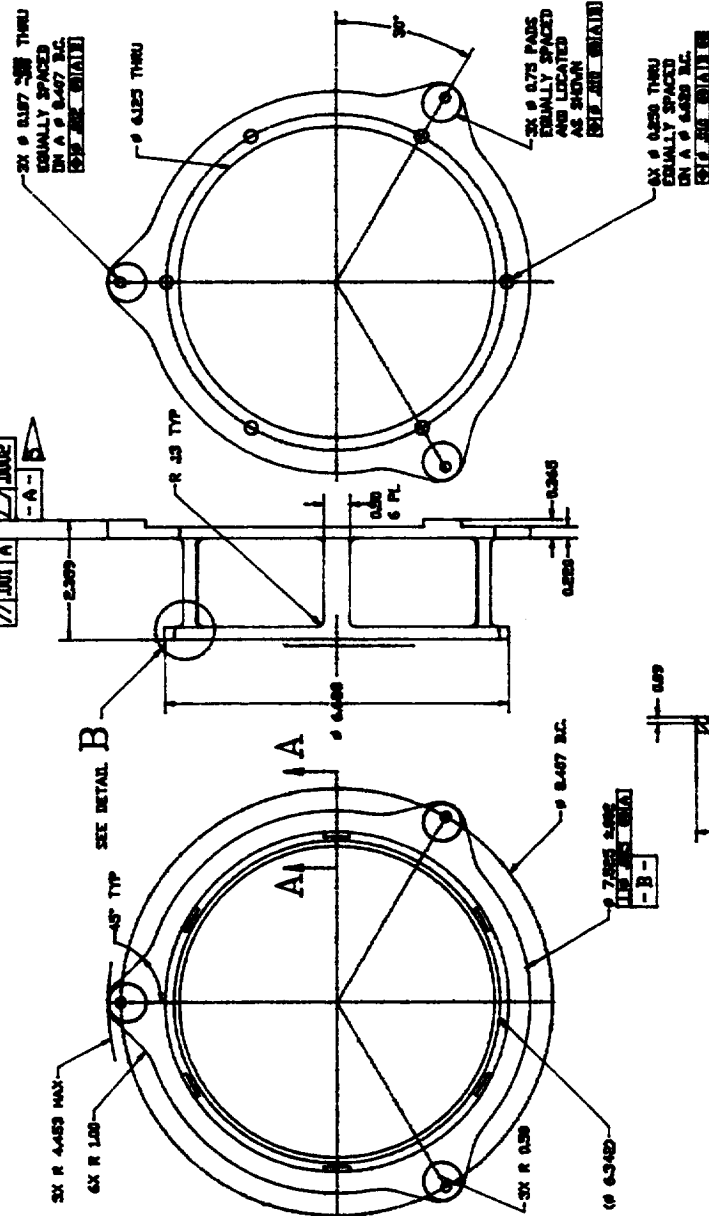
**Center for Applied Options
University of Alabama in Huntsville
Huntsville, AL 35894**

HASS
MOUNTING PLATE
(SXI PROTOTYPE)

SXI0064C
' 1



DETAIL SCALE: 2/1
A



NOTES:

1. MATERIAL: CRES 300 SERIES (CRES 310 OR 316 PREFERRED)
2. REMOVE ALL BURRS AND BREAK SHARP EDGES.
3. 100% ALL MACHINED SURFACES UNLESS OTHERWISE SPECIFIED.
4. ALL FILLET RADIi ARE TO BE .03 MAX. UNLESS OTHERWISE SPECIFIED.
5. DATUM -A- IS A PLANE DEFINED BY ALL 3 PADS.

3
5900IXS

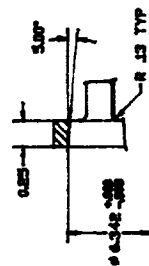


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Huntsville, AL 35894**

CSX MIRROR MOUNT
(CSX PROTOTYPE)

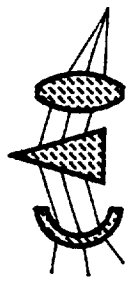
35900IXS

SECTION A-A
SCALE: 2 1/4"
6 PL. 60' APART



NOTES:

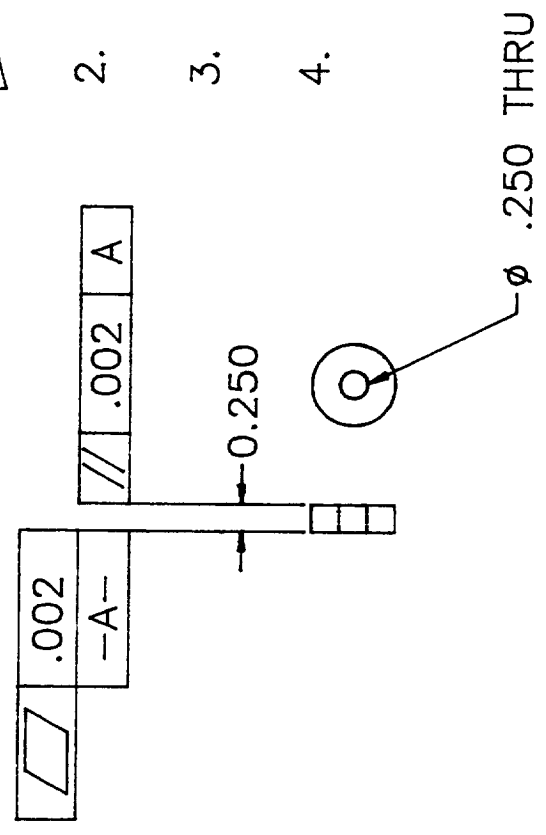
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PER QQ-A-250/11.
2. REMOVE ALL BURRS AND BREAK SHARP
EDGES.
3. 125/ ALL MACHINED SURFACES UNLESS
OTHERWISE SPECIFIED.
4. ALL FILLET RADII ARE TO BE .03 MAX.
UNLESS OTHERWISE SPECIFIED.



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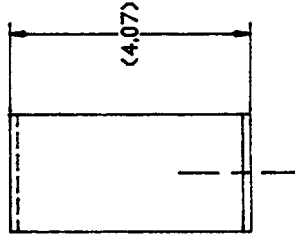
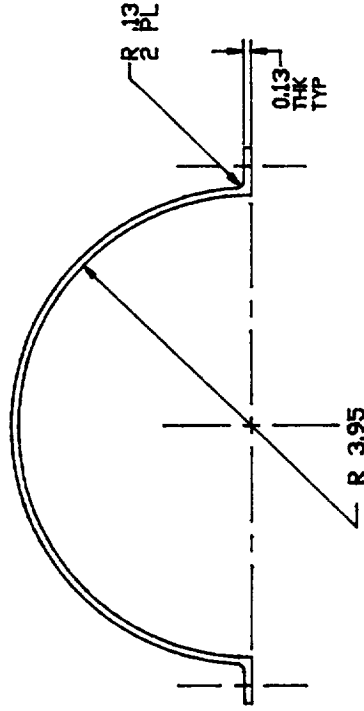
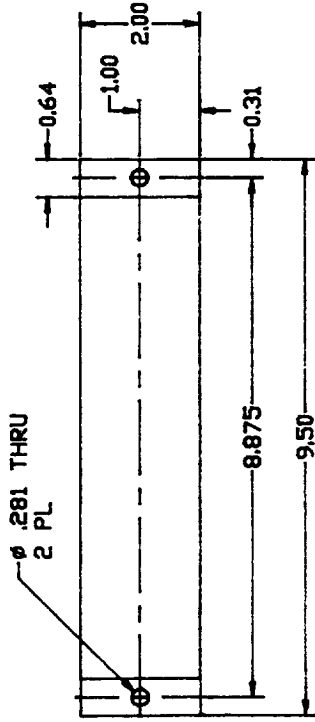
AUG 14, 1993
CAMERA ASSEMBLY
SPACERS
(SXI PROTOTYPE)

SXI0066A



NOTES:

1. MATERIAL: ALUMINUM ALLOY 6061-T6 PER QQ-A-250/11.
2. REMOVE ALL BURRS AND BREAK SHARP EDGES.
3. 125/ ALL MACHINED SURFACES UNLESS OTHERWISE SPECIFIED.
4. ALL FILLET RADII ARE TO BE .03 MAX. UNLESS OTHERWISE SPECIFIED.



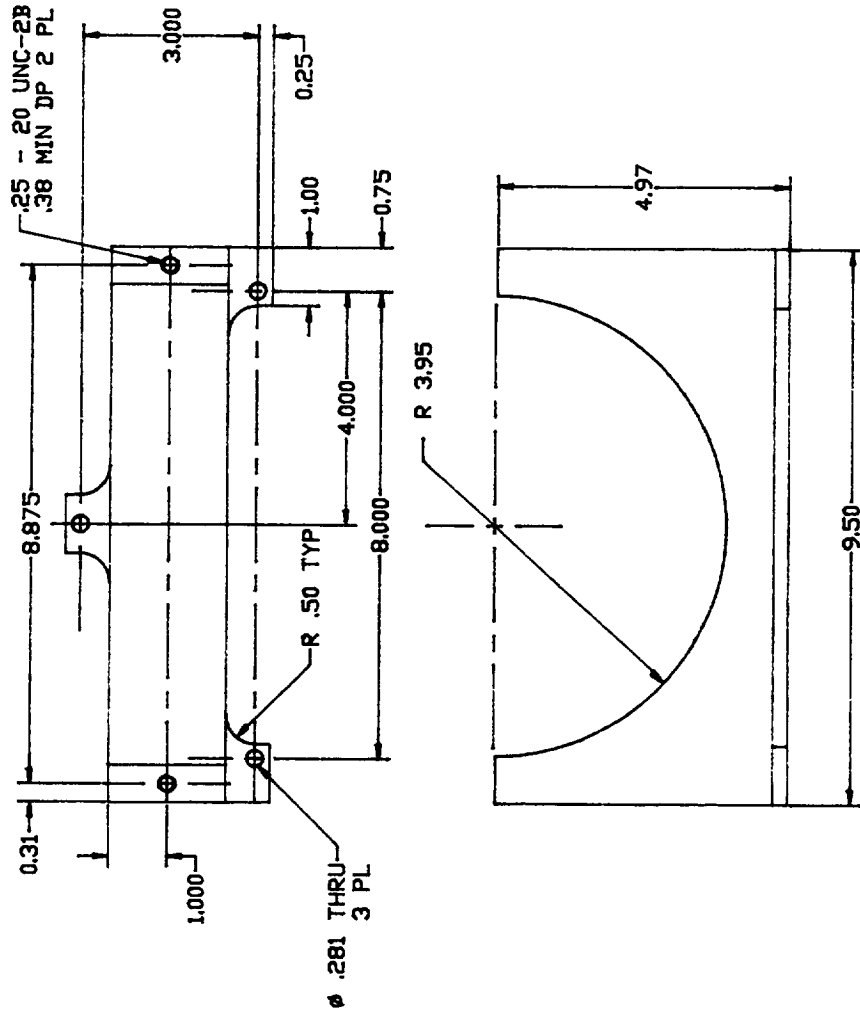
SXI0067
A



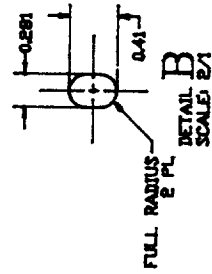
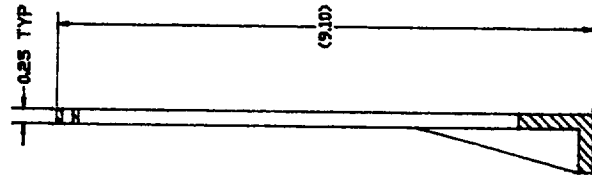
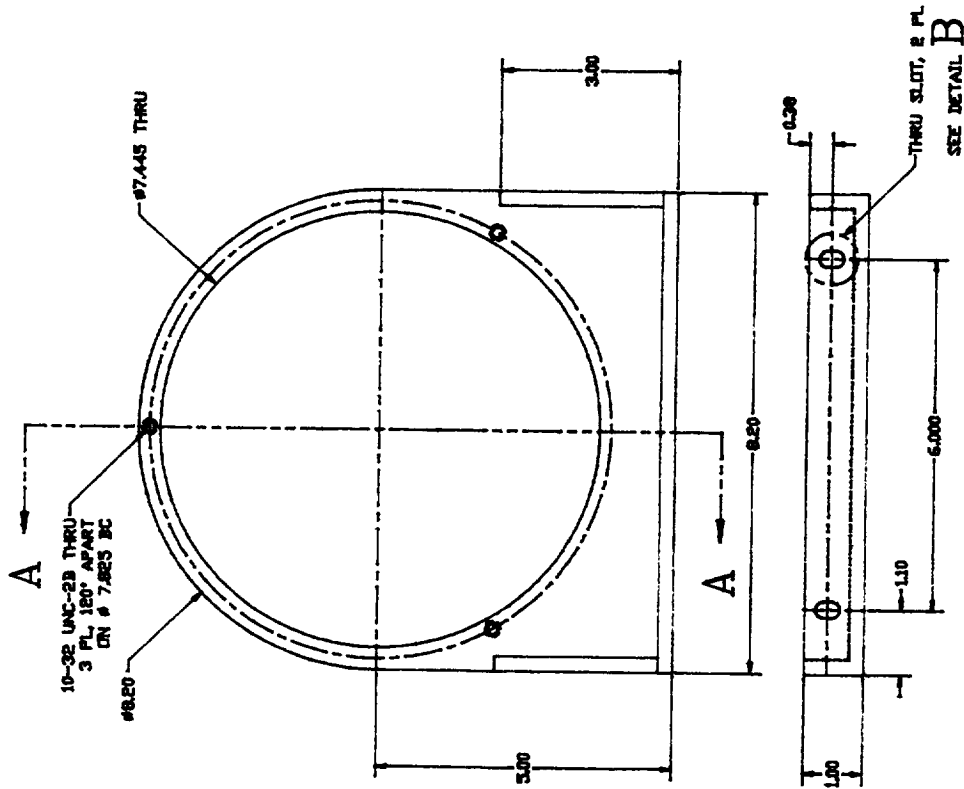
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Huntsville, AL 35894

TELESCOPE MOUNT
(SXI PROTOTYPE)

SXI0067A
1



SXI0067
A



NOTES:

1. MATERIAL: ALUMINUM ALLOY 6061-T6 PER QQ-A-250/11.
2. REMOVE ALL BURRS AND BREAK SHARP EDGES.
3. 125° ALL MACHINED SURFACES UNLESS OTHERWISE SPECIFIED.
4. ALL FILLET RADII ARE TO BE .03 MAX. UNLESS OTHERWISE SPECIFIED.

SX10069



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APERTURE PLATE
MOUNT
(SXI PROTOTYPE)

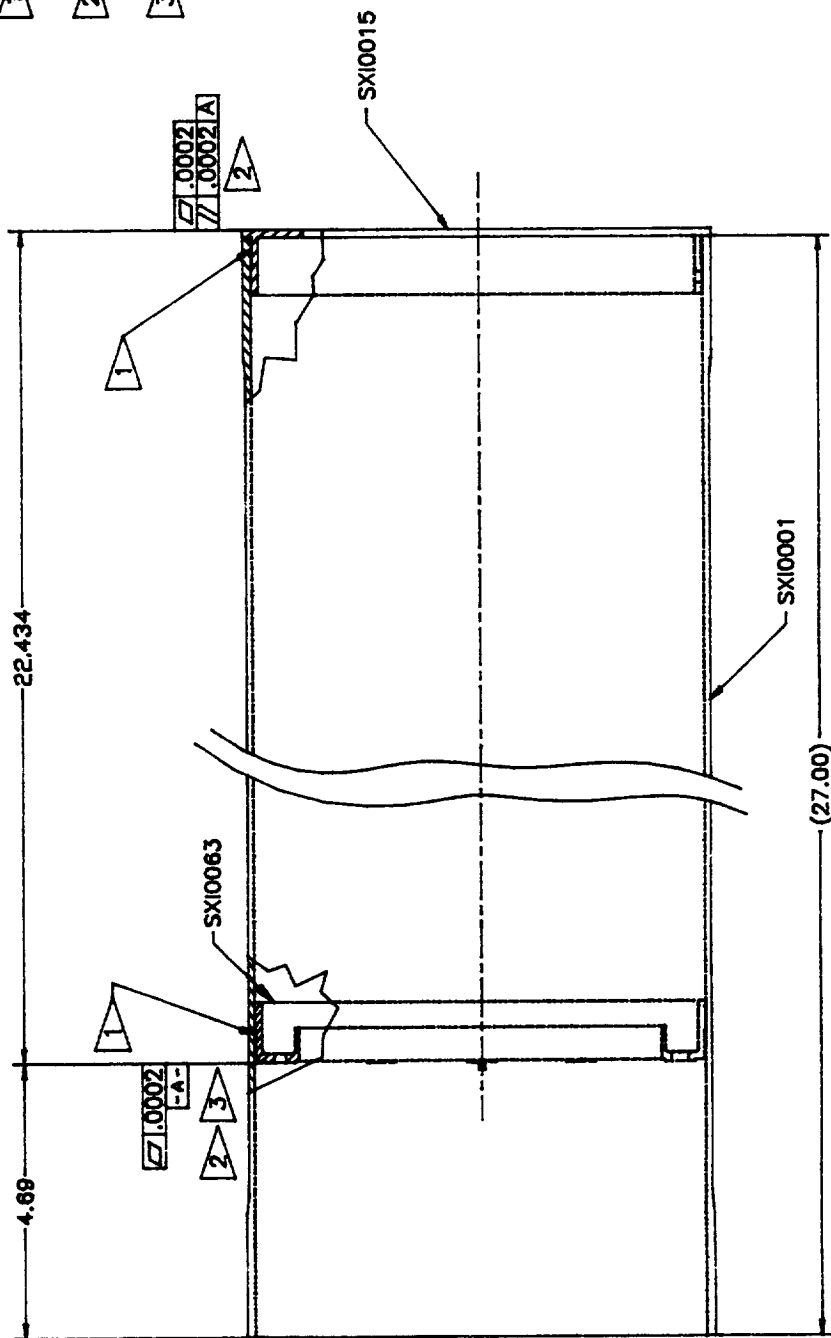
SX10069

1/2

A CHANGED OPTICAL BENCH NAME AA
LENGTH TO 27.00 IN.

NOTES:

- 1 ASSEMBLE PER OPTICAL BENCH
ASSEMBLY PROCEDURE.
- 2 THESE TOLERANCES APPLY TO
AFTER ASSEMBLY CONDITION.
- 3 DATUM -A- IS DEFINED BY
ALL 8 PADS ON SX10063.



SX10070
A



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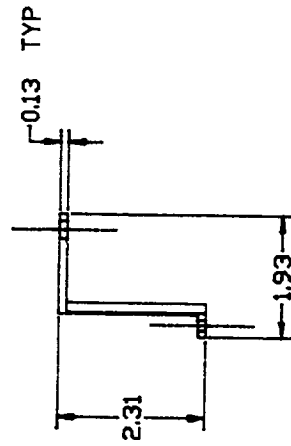
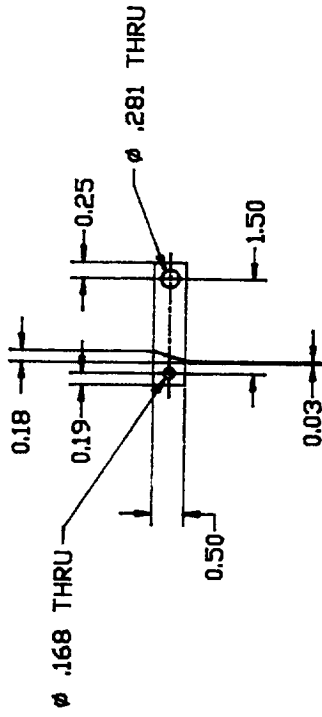
PROTOTYPE
OPTICAL BENCH
ASSY (LONG)

SX10070A

1

NOTES:

1. MATERIAL: ALUMINUM ALLOY 6061-T6
PER QQ-A-250/11.
2. REMOVE ALL BURRS AND BREAK SHARP
EDGES.
3. 125°/ALL MACHINED SURFACES UNLESS
OTHERWISE SPECIFIED.
4. ALL FILLET RADII ARE TO BE .03 MAX.
UNLESS OTHERWISE SPECIFIED.



SX10071



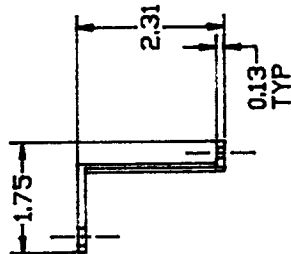
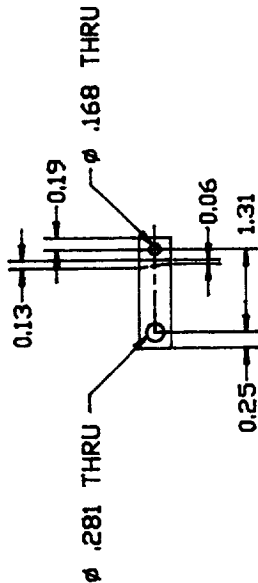
Center for Applied Optics
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Huntsville, AL 35899

ADJ. BRACKET #1
SXI CAMERA ASSY

SX10071

NOTES:

1. MATERIAL: ALUMINUM ALLOY 6061-T6
PER QQ-A-250/11.
2. REMOVE ALL BURRS AND BREAK SHARP
EDGES.
3. $\sqrt{R2}$ ALL MACHINED SURFACES UNLESS
OTHERWISE SPECIFIED.
4. ALL FILLET RADII ARE TO BE .03 MAX.
UNLESS OTHERWISE SPECIFIED.



SXI0072



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Huntsville, AL 35899

ADJ. BRACKET #2
SXI CAMERA ASSY

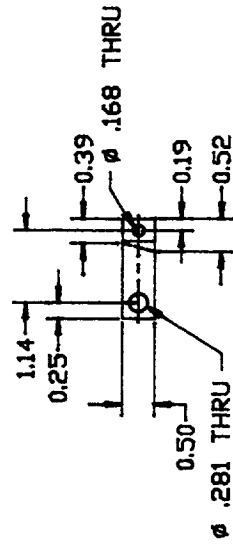
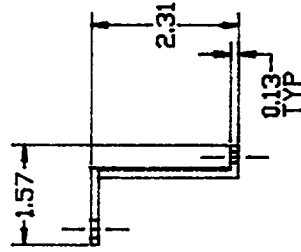
SXI0072

1

NOTES:

1. MATERIAL: ALUMINUM ALLOY 6061-T6
PER QQ-A-250/11.

2. REMOVE ALL BURRS AND BREAK SHARP EDGES.
3. 125° ALL MACHINED SURFACES UNLESS OTHERWISE SPECIFIED.
4. ALL FILLET RADII ARE TO BE .03 MAX. UNLESS OTHERWISE SPECIFIED.



SX10073



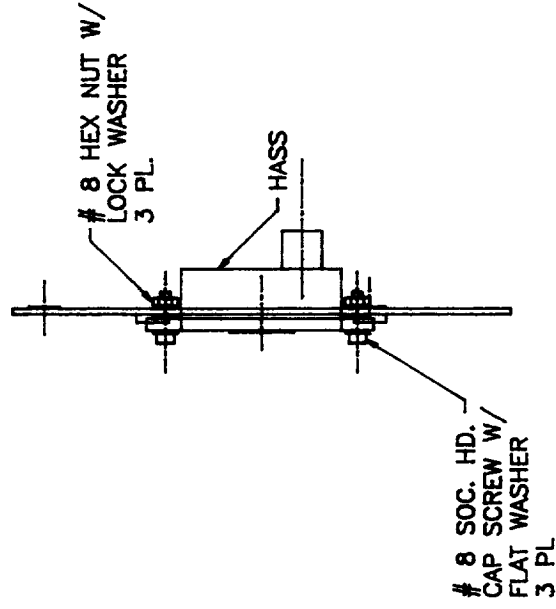
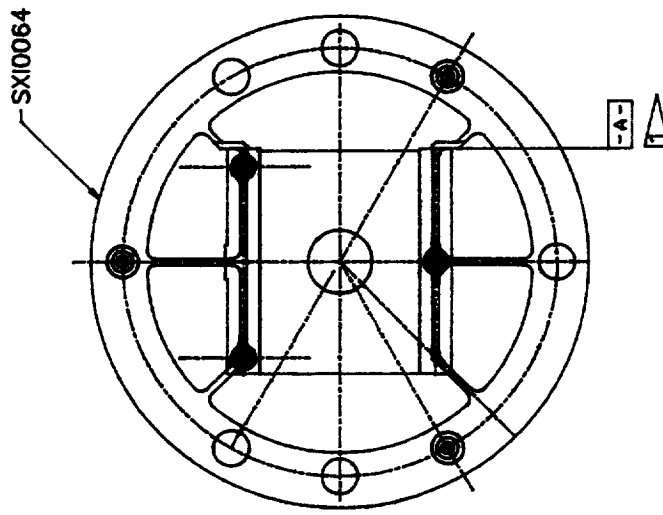
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University of Alabama in Huntsville
Huntsville, AL 35899

ADJ. BRACKET #3
SXI CAMERA ASSY

SX10073

NOTES:

REGISTER REFERENCE EDGE
OF SUN SENSOR AGAINST
DATUM --A-- (DEFINED BY
THE TWO PADS) BEFORE
TIGHTENING THE NUTS.



SXI0074

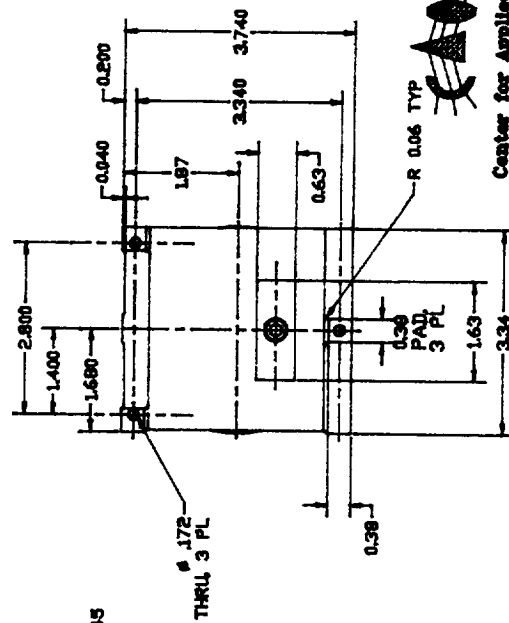
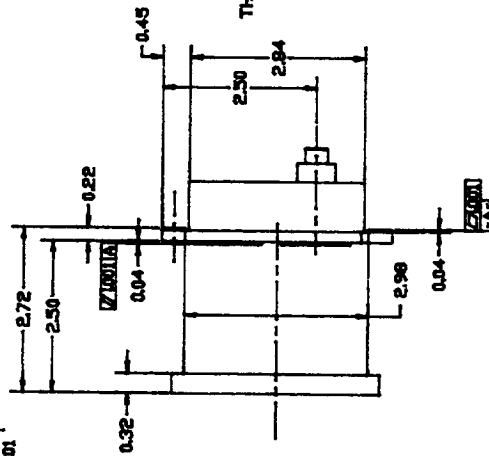
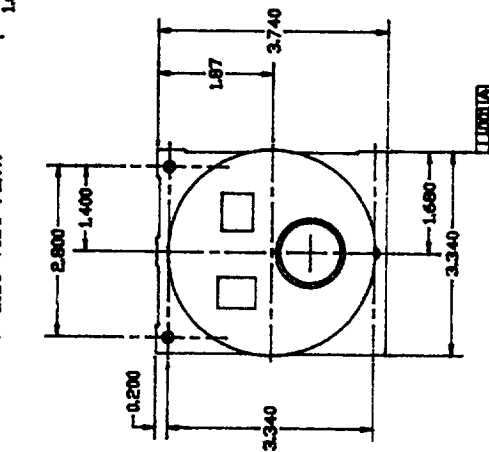
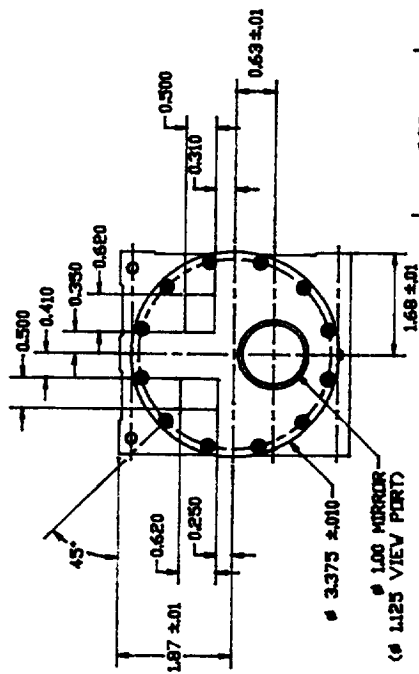


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Huntsville, AL 35899

SUN SENSOR/
MOUNTING PLATE
ASSEMBLY

SXI0074
1 1

1/1



NOTES:

△ MATERIAL: ALUMINUM ALLOY 6061-T6
PER QQ-A-250/11.

2. REMOVE ALL BURRS AND BREAK SHARP EDGES.

3. 125/ ALL MACHINED SURFACES UNLESS OTHERWISE SPECIFIED.

4. ALL FILLET RADII ARE TO BE .03 MAX. UNLESS OTHERWISE SPECIFIED.

SX10075



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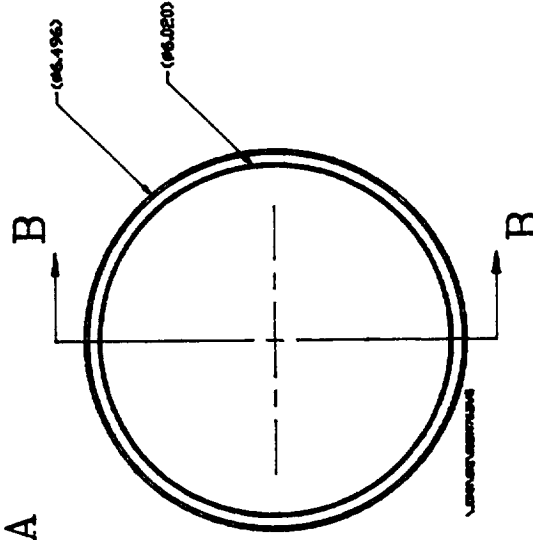
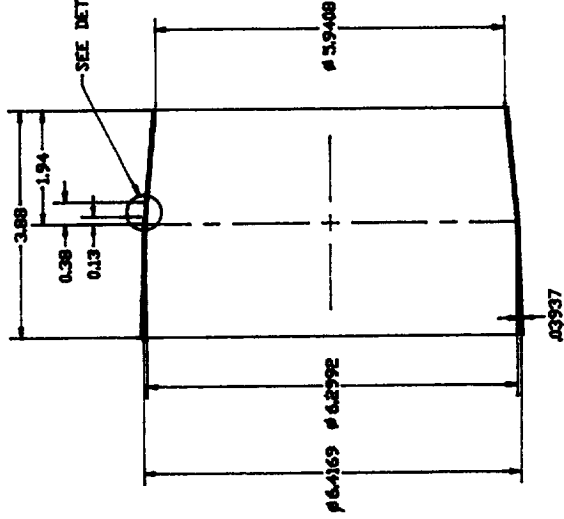
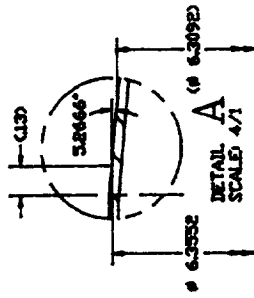
**SXI SUN SENSOR
MODEL**

SXI0075

2

NOTES:

1. MATERIAL: NICKEL.
2. REMOVE ALL BURRS AND BREAK SHARP EDGES.
3. 125° ALL MACHINED SURFACES UNLESS OTHERWISE SPECIFIED.
4. ALL FILLET RADIUS ARE TO BE .03 MAX. UNLESS OTHERWISE SPECIFIED.



SXI0076
A

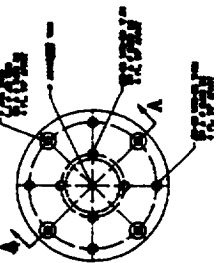
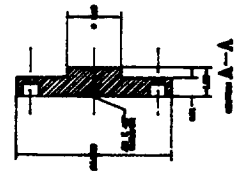
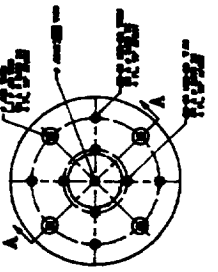
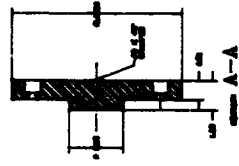
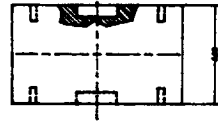
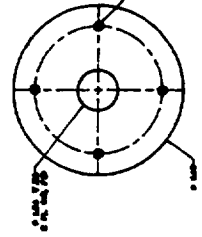
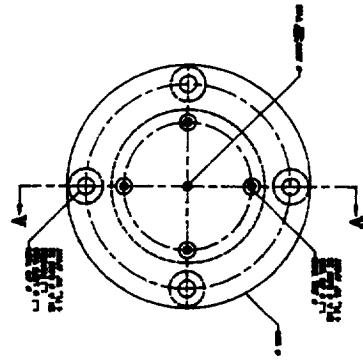


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Huntsville, AL 35894

SXI
ELECTROFORMED
MIRROR

SXI0076A
1

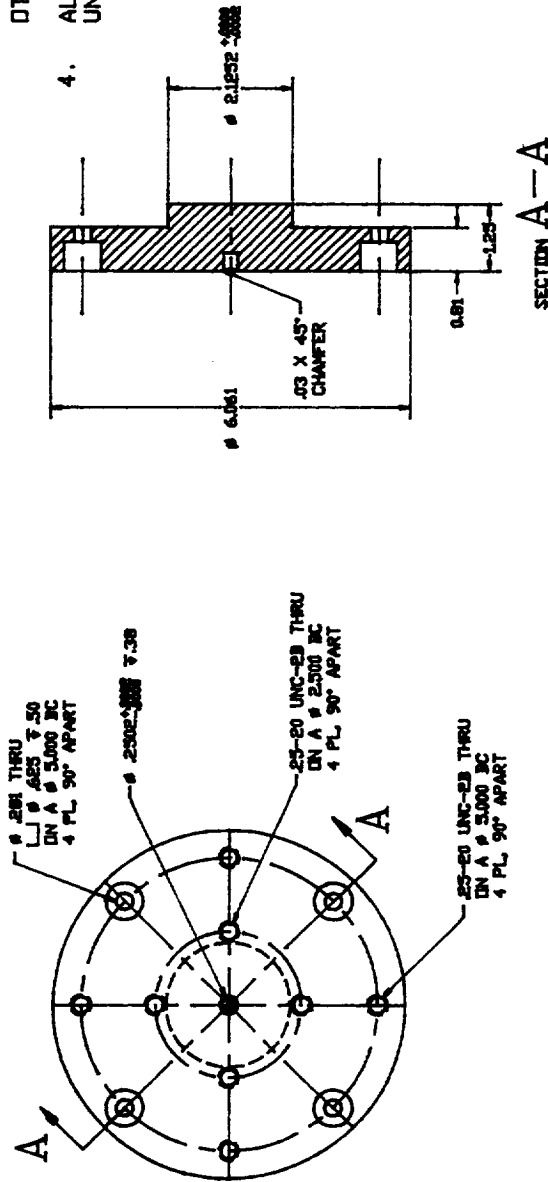
1/1



SXI0077A.DWG

NOTES:

1. MATERIAL: ALUMINUM ALLOY 6061-T6
PER QQ-A-250/11.
2. REMOVE ALL BURRS AND BREAK SHARP
EDGES.
3. 125° ALL MACHINED SURFACES UNLESS
OTHERWISE SPECIFIED.
4. ALL FILLET RADII ARE TO BE .03 MAX.
UNLESS OTHERWISE SPECIFIED.



SX10078

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LEFT FLANGE
ROUGH MACHINING
SXI MIRROR MANDREL

SX10078

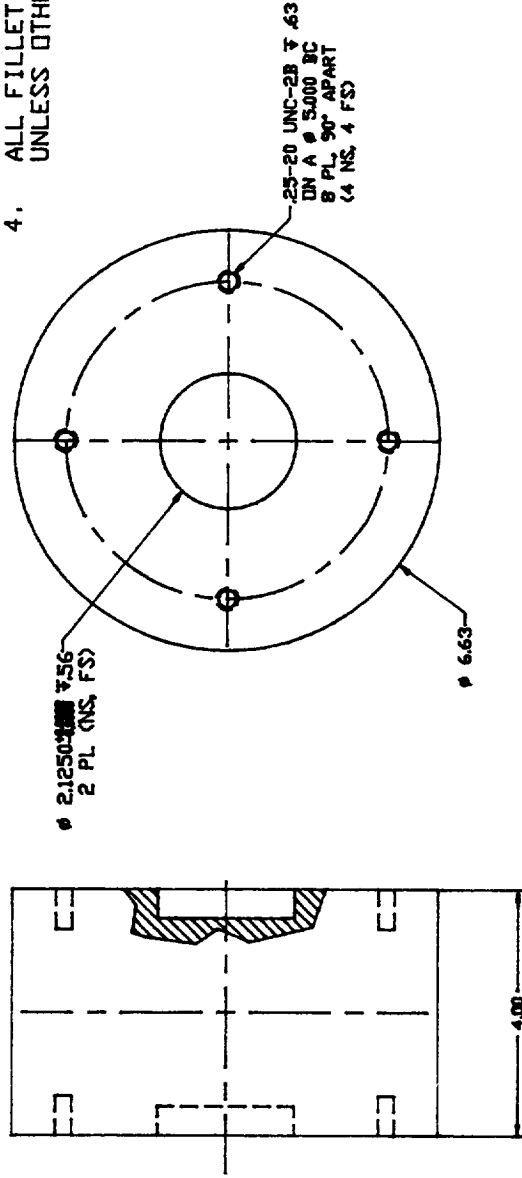
NOTES:

1. MATERIAL: ALUMINUM ALLOY 6061-T6
PER QQ-A-250/11.

2. REMOVE ALL BURRS AND BREAK SHARP
EDGES.

3. 125°/ALL MACHINED SURFACES UNLESS
OTHERWISE SPECIFIED.

4. ALL FILLET RADII ARE TO BE .03 MAX.
UNLESS OTHERWISE SPECIFIED.



SXI0079



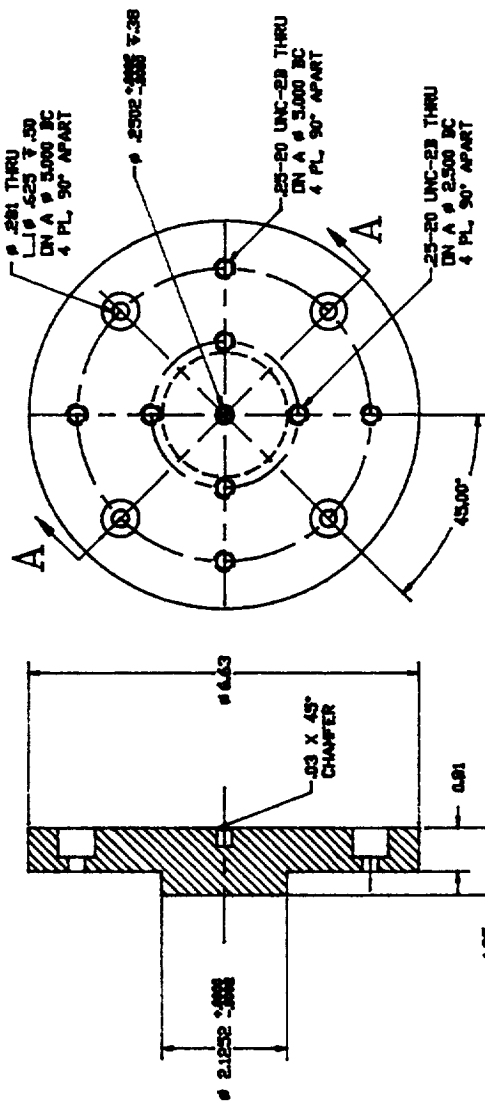
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University of Alabama in Huntsville
Huntsville, AL 35894

MIDDLE BLOCK
ROUGH MACHINING
SXI MIRROR MANDREL

SXI0079

NOTES:

1. MATERIAL: ALUMINUM ALLOY 6061-T6 PER QQ-A-250/11.
2. REMOVE ALL BURRS AND BREAK SHARP EDGES.
3. 125/ ALL MACHINED SURFACES UNLESS OTHERWISE SPECIFIED.
4. ALL FILLET RADII ARE TO BE .03 MAX. UNLESS OTHERWISE SPECIFIED.



SECTION A-A

SX10080



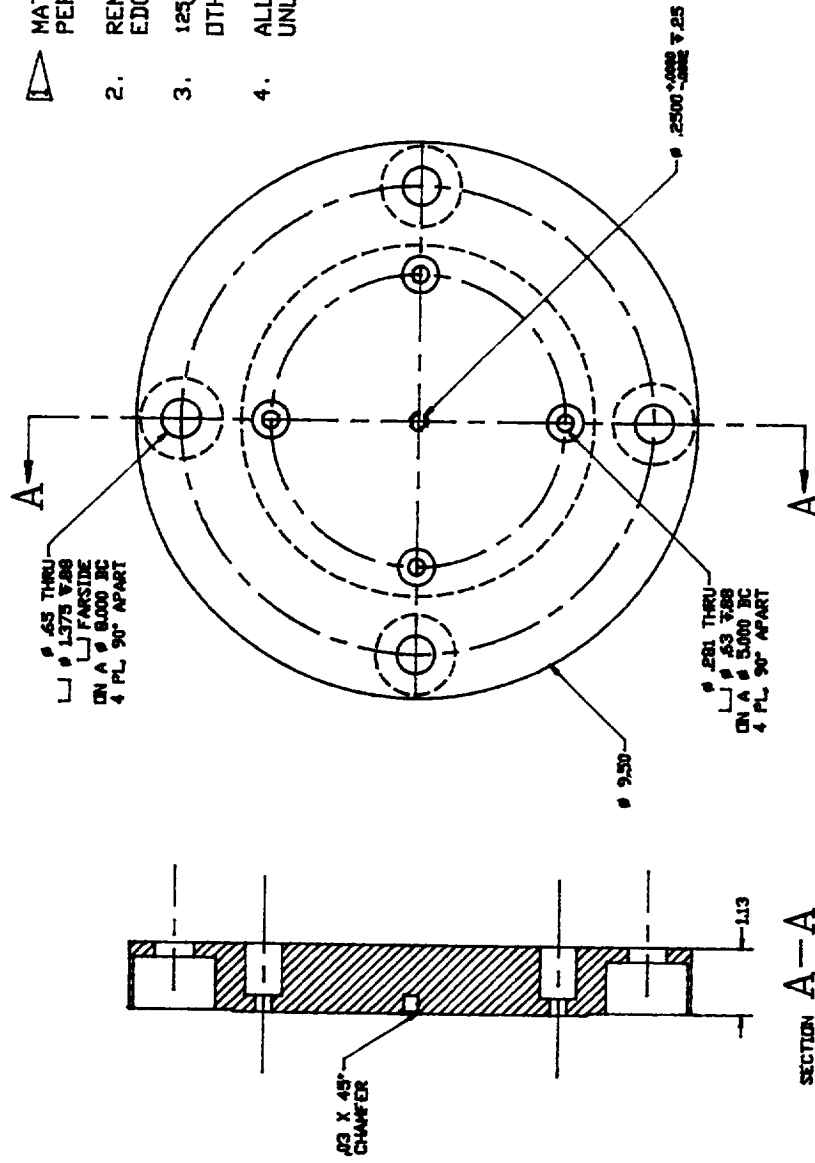
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University of Alabama in Huntsville
Huntsville, AL 35894

RIGHT FLANGE
ROUGH MACHINING
SXI MIRROR MANDREL

SX10080
1 1

NOTES:

1. MATERIAL: ALUMINUM ALLOY 6061-T6
PER QQ-A-250/11.
2. REMOVE ALL BURRS AND BREAK SHARP
EDGES.
3. 125/ ALL MACHINED SURFACES UNLESS
OTHERWISE SPECIFIED.
4. ALL FILLET RADII ARE TO BE .03 MAX.
UNLESS OTHERWISE SPECIFIED.



SX10081



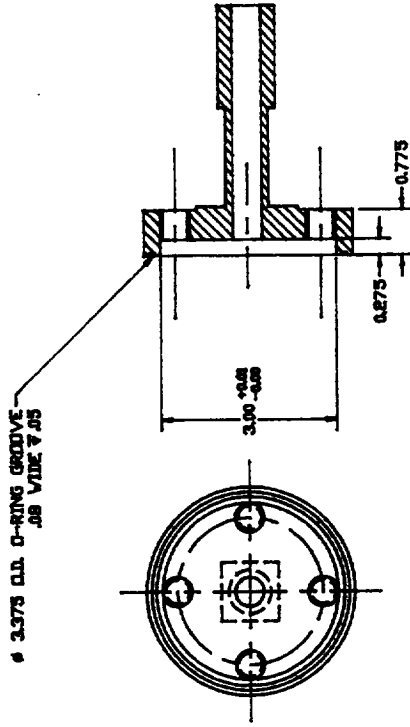
Center for Applied Optics
University of Alabama in Huntsville
Huntsville, AL 35894

MACHINING PLATE
ROUGH MACHINING
SXI MIRROR MANDREL

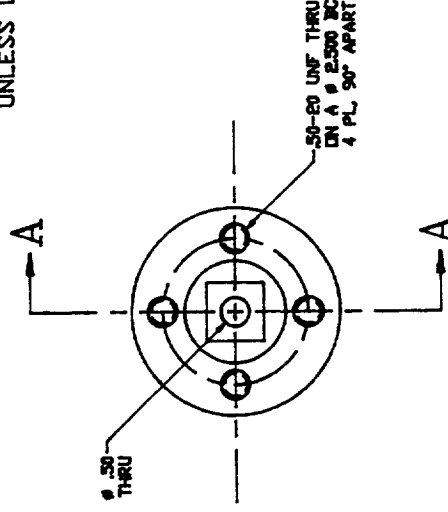
SX10081

NOTES:

1. MATERIAL: CPVC PLASTIC.
2. REMOVE ALL BURRS AND BREAK SHARP EDGES.
3. 125°/ALL MACHINED SURFACES UNLESS OTHERWISE SPECIFIED.
4. ALL FILLET RADII ARE TO BE .03 MAX. UNLESS OTHERWISE SPECIFIED.



SECTION A-A



SX10082

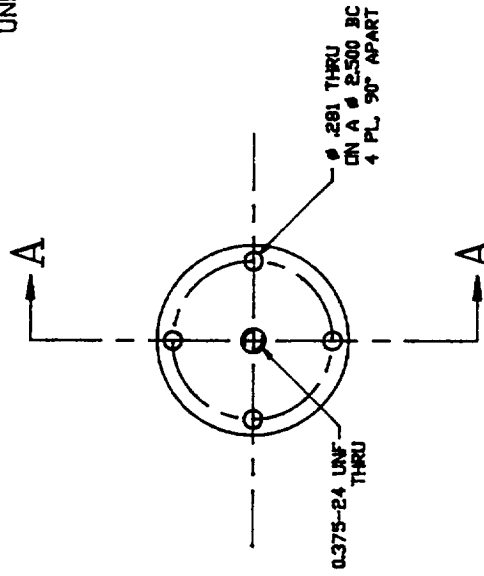

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PLATING SHAFT
RETAINER
SXI MIRROR MANDREL

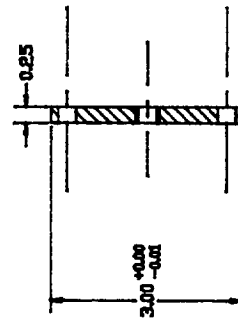
SX10082

NOTES:

1. MATERIAL: STAINLESS STEEL 300 SERIES.
2. REMOVE ALL BURRS AND BREAK SHARP EDGES.
3. 125/ ALL MACHINED SURFACES UNLESS OTHERWISE SPECIFIED.
4. ALL FILLET RADII ARE TO BE .03 MAX. UNLESS OTHERWISE SPECIFIED.



SXI0083



SECTION A-A



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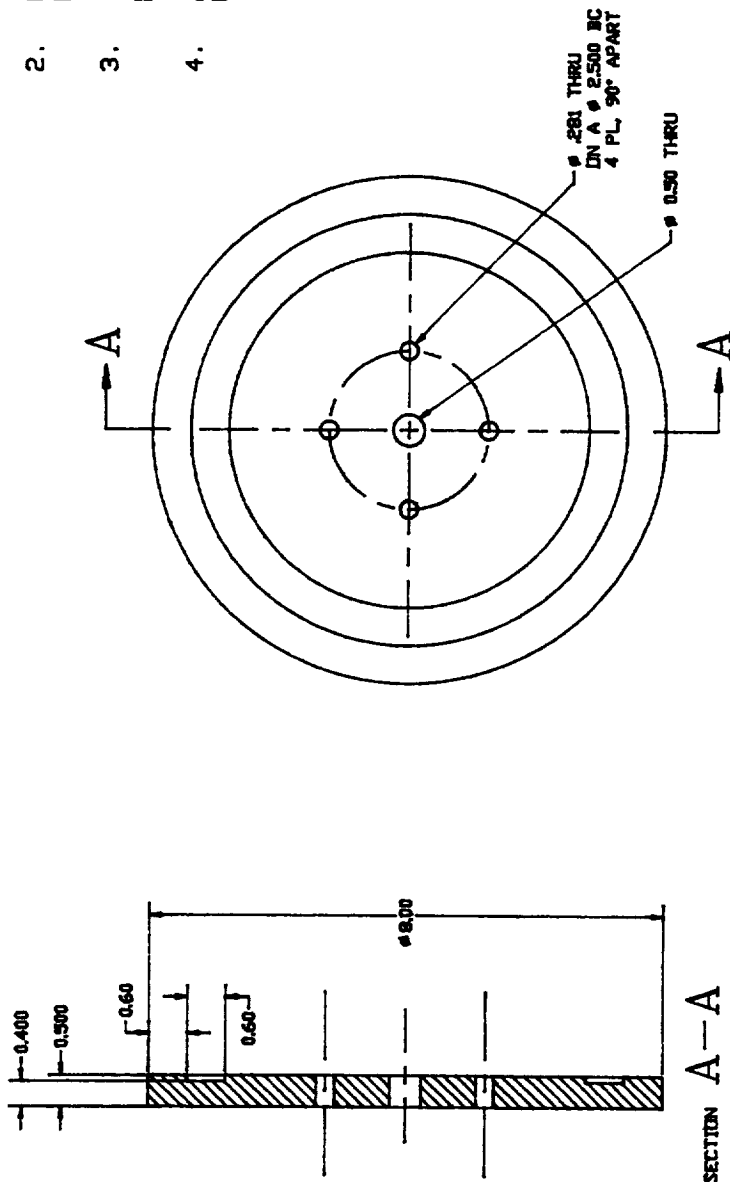
SXI MIRROR MANDREL
RETAINER PLATE


SXI0083
1 1

NOTES:

1. MATERIAL: CPVC OR POLYPROPYLENE OR HI-DENSITY POLYETHYLENE. PLASTIC MUST WITHSTAND BOILING WATER.
2. REMOVE ALL BURRS AND BREAK SHARP EDGES.
3. 125 / ALL MACHINED SURFACES UNLESS OTHERWISE SPECIFIED.
4. ALL FILLET RADII ARE TO BE .03 MAX. UNLESS OTHERWISE SPECIFIED.

SXI0084



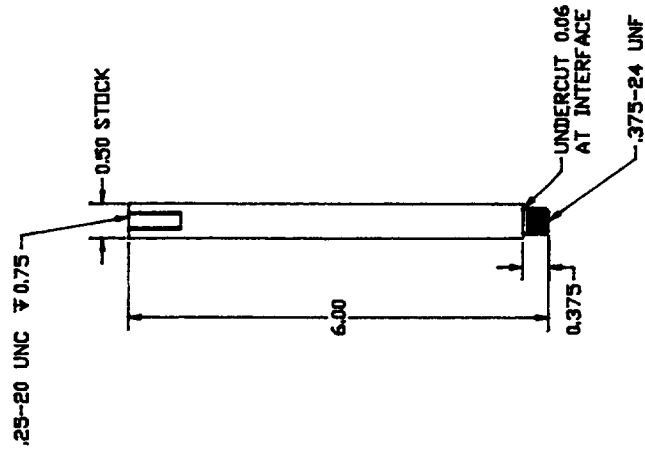

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 Huntsville, AL 35899

TOP PLATING SHIELD
 SXI MIRROR MANDREL

SXI0084

NOTES:

1. MATERIAL: STAINLESS STEEL 300 SERIES.
2. REMOVE ALL BURRS AND BREAK SHARP EDGES.
3. 125/ ALL MACHINED SURFACES UNLESS OTHERWISE SPECIFIED.
4. ALL FILLET RADII ARE TO BE .03 MAX. UNLESS OTHERWISE SPECIFIED.



SXI0085



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Huntsville, AL 35899

DATE: 10-10-88

PLATING SHAFT
SXI MIRROR MANDREL

SXI0085

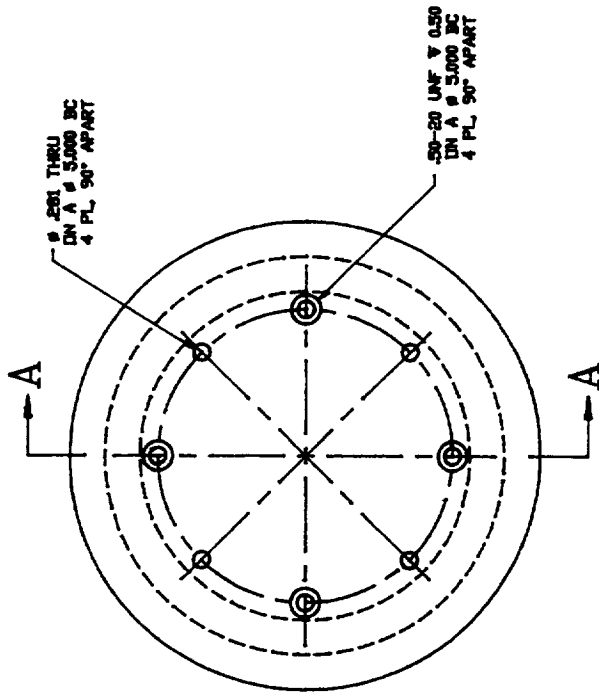
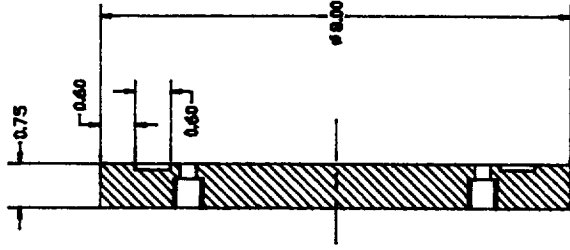
NOTES:

1. MATERIAL: CPVC OR POLYPROPYLENE OR HI-DENSITY POLYETHYLENE. PLASTIC MUST WITHSTAND BOILING WATER.

2. REMOVE ALL BURRS AND BREAK SHARP EDGES.

3. 125° ALL MACHINED SURFACES UNLESS OTHERWISE SPECIFIED.

4. ALL FILLET RADII ARE TO BE .03 MAX. UNLESS OTHERWISE SPECIFIED.



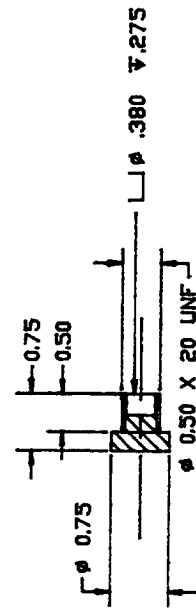
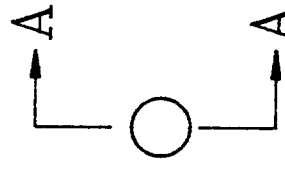
SXI0086
A



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Huntsville, AL 35890

BOTTOM PLATING
SHIELD
SXI MIRROR MANDREL

SXI0086A
1 1



SECTION A-A

(QUANTITY: 8)

NOTES:

1. MATERIAL: CPVC PLACTIC.

2. REMOVE ALL BURRS AND BREAK SHARP EDGES.
3. 125/ ALL MACHINED SURFACES UNLESS OTHERWISE SPECIFIED.
4. ALL FILLET RADII ARE TO BE .03 MAX. UNLESS OTHERWISE SPECIFIED.



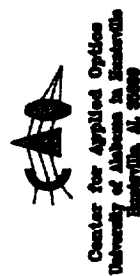
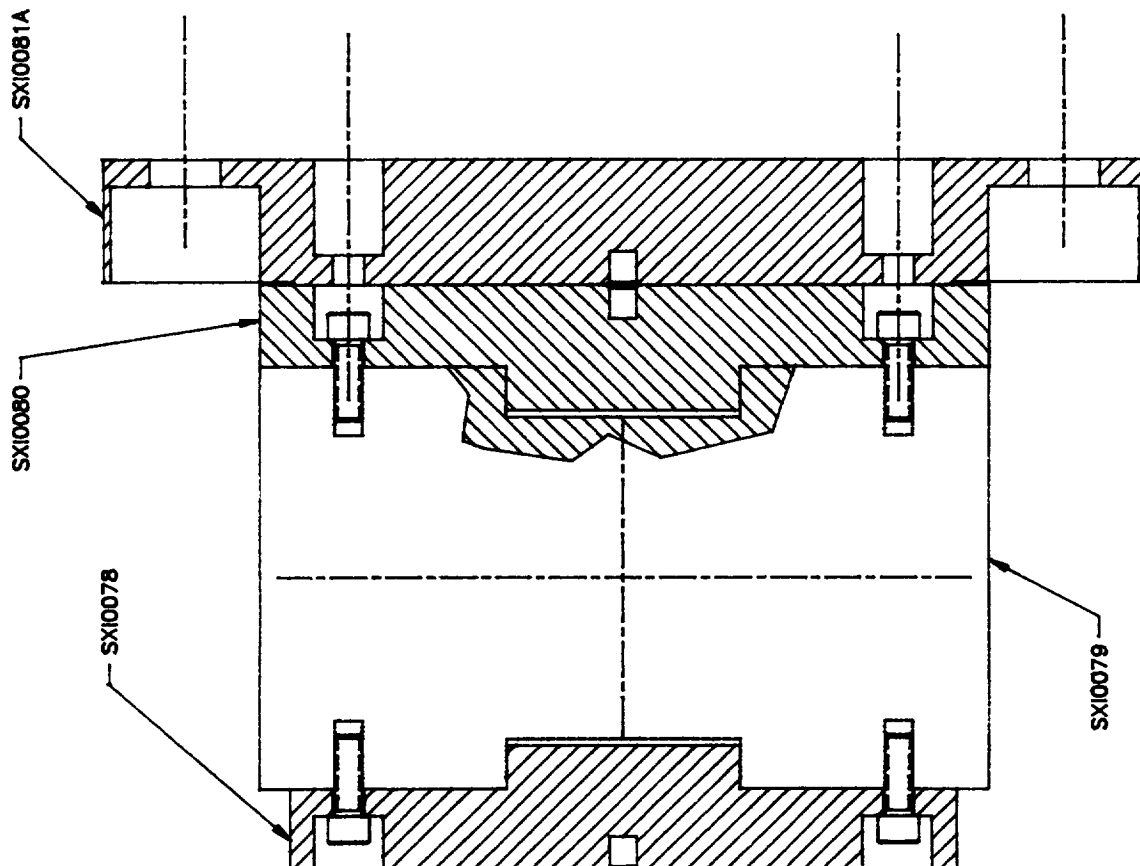
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REV. 10. 1988

PLATING PLUGS
SXI MANDREL ASSY

SXI0087
1 1

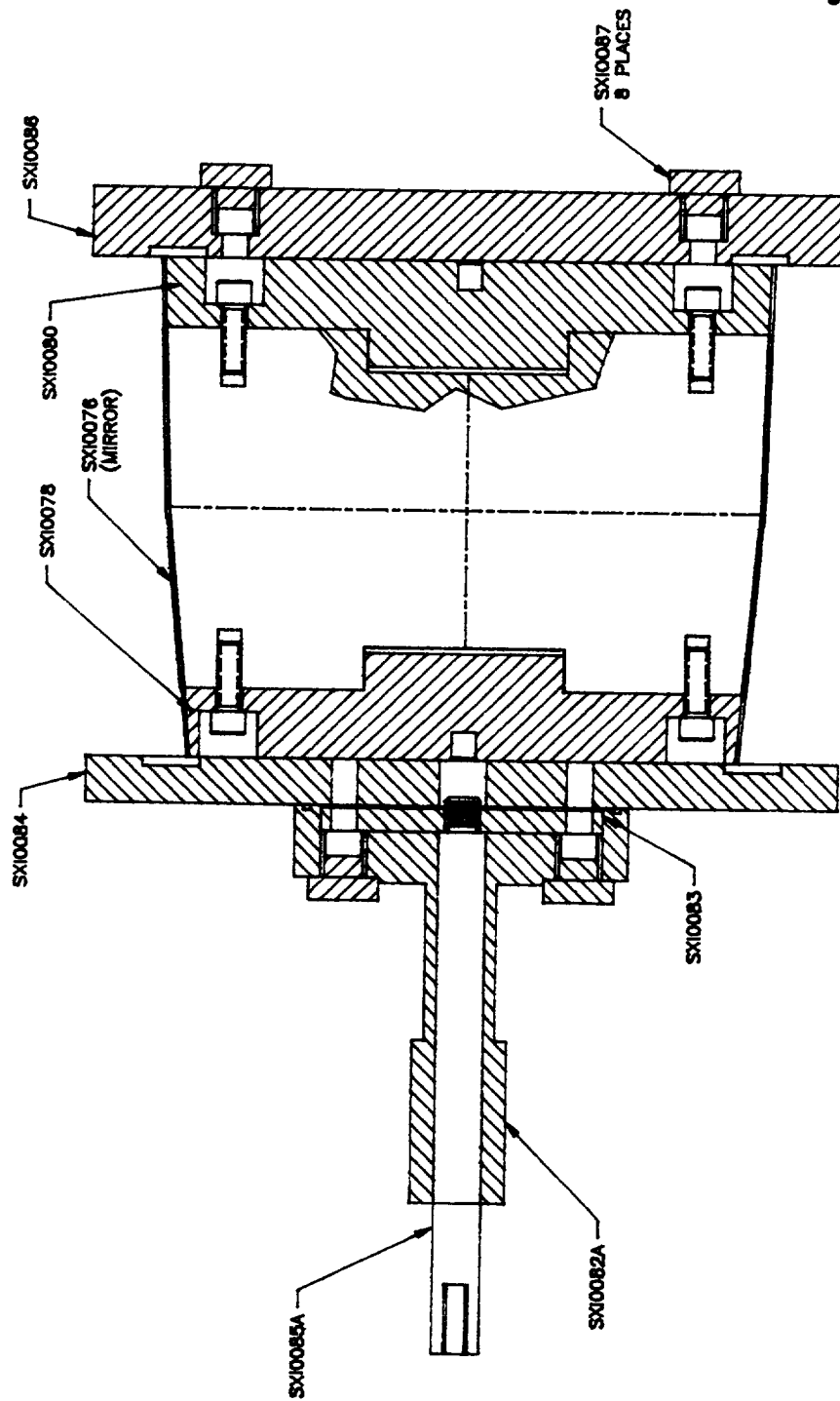
1/1



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MANDREL ASSEMBLY ROUGH MACHINING PROTOTYPE SXI MIRROR

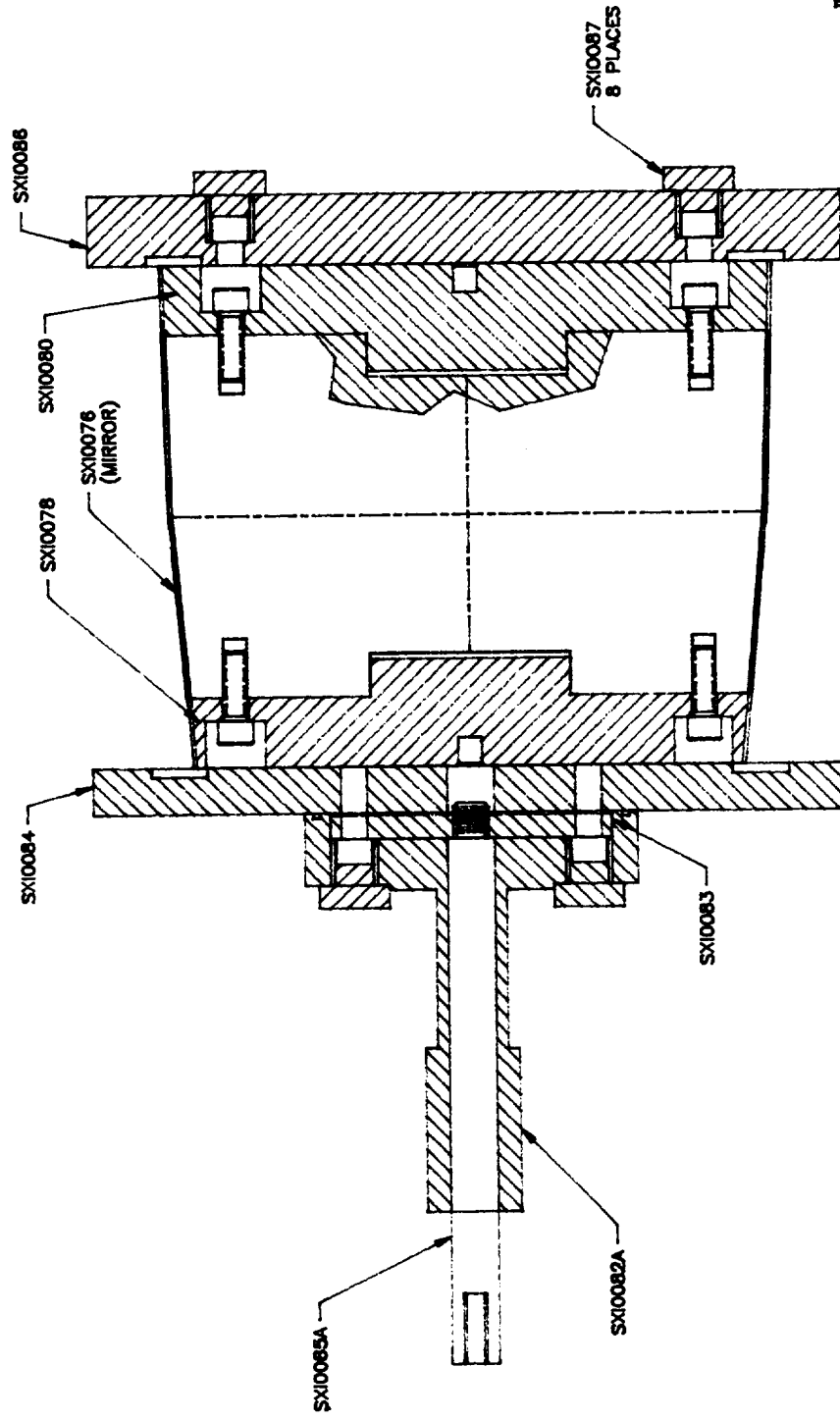
SXI\SXI\ SXI0088.DWG
OCT. 16, 1993



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Huntsville, AL 35894

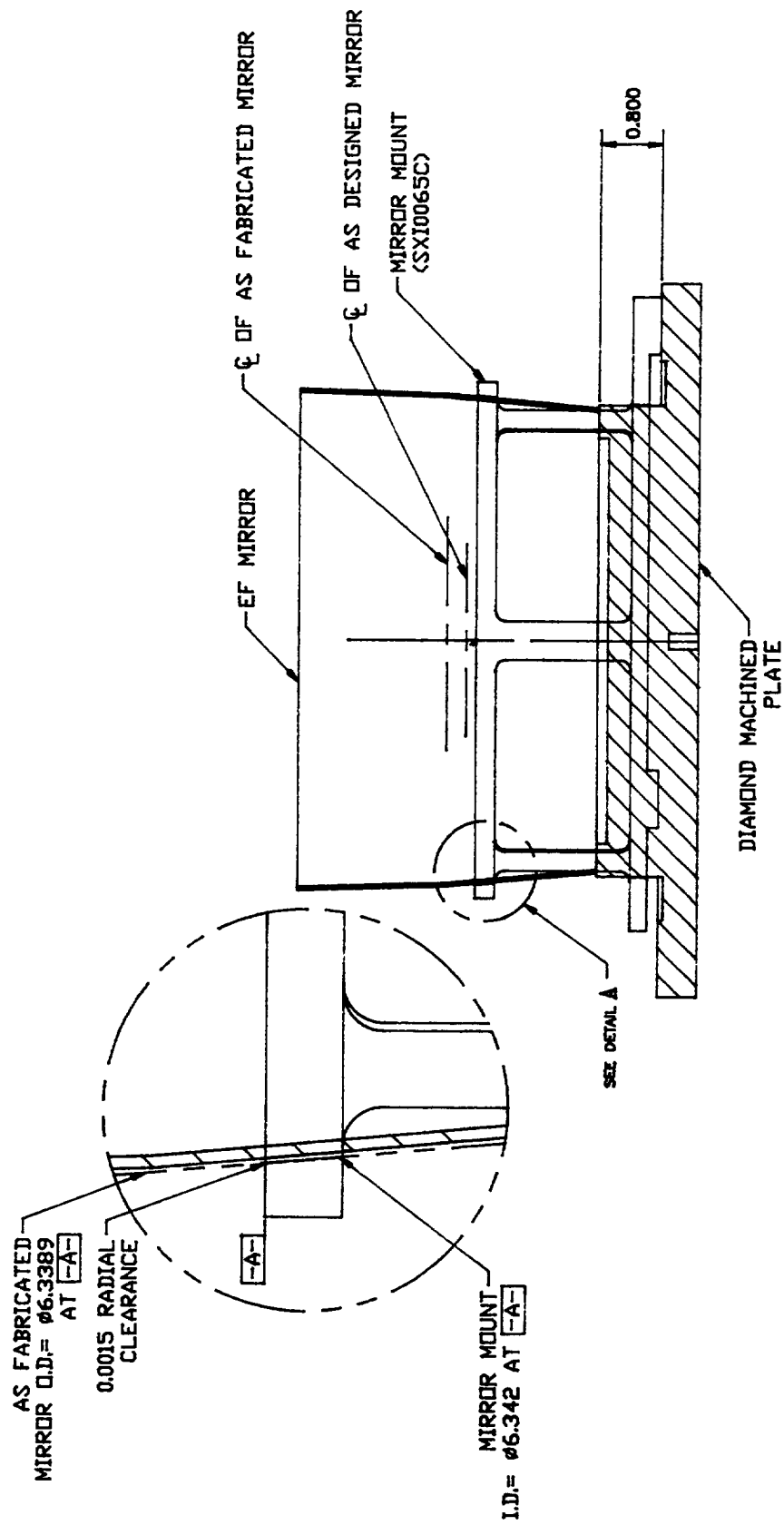
MANDREL ASSEMBLY (PLATING) PROTOTYPE SXI MIRROR

SXI\SXI\ SX10086.DWG
OCT. 16, 1993



MANDREL ASSEMBLY (PLATING) PROTOTYPE SXI MIRROR

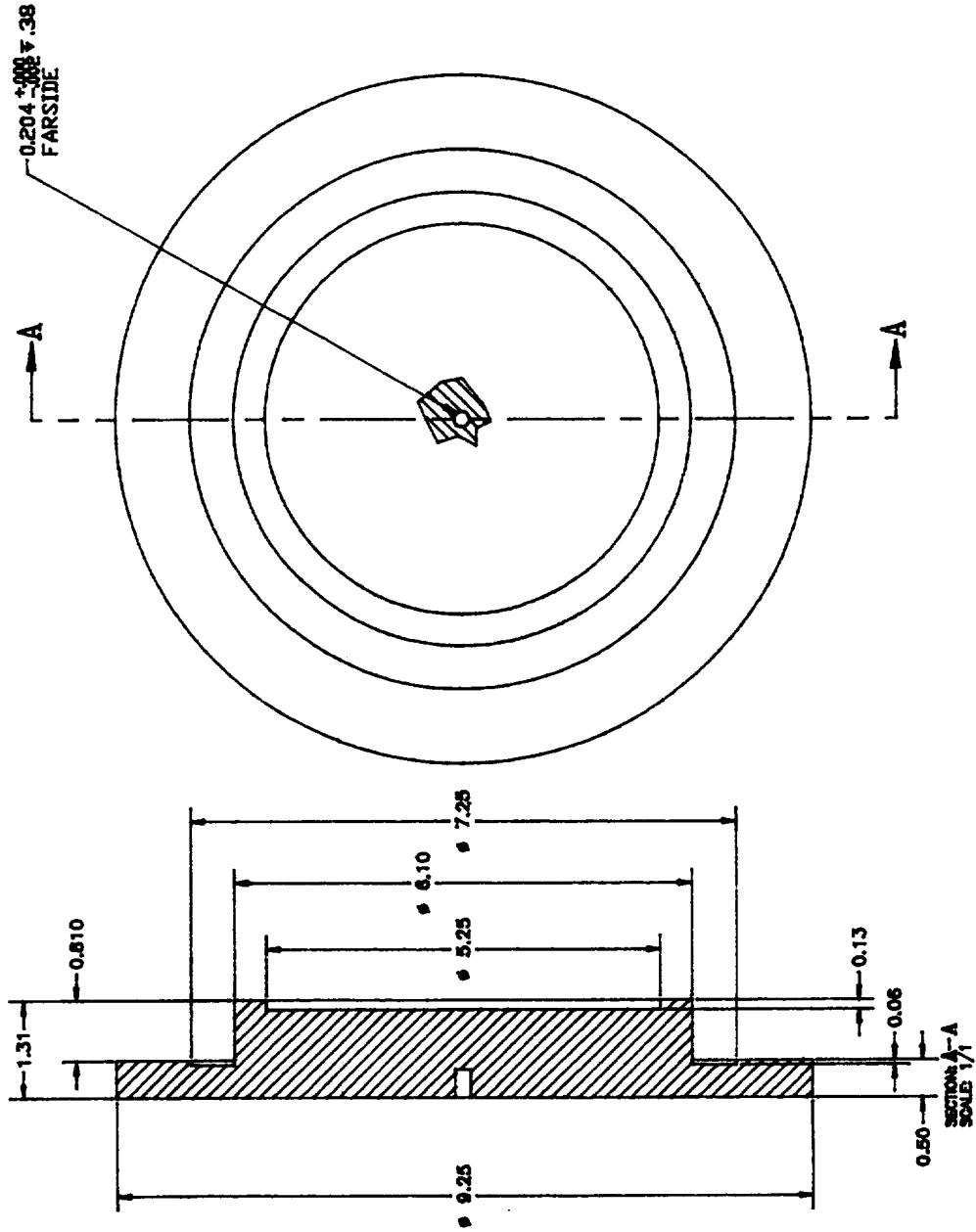
SXI\SXI\ SXI\ SX10089.DWG
 OCT. 16, 1993



ASSY FIXTURE LAYOUT (OPTION: 2)
PROTOTYPE SXI MIRROR

SXI\ SXI\ 800090.DWG
AUG. 22, 1994


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University of Arizona in Tucson
Tucson, AZ 85724



NOTES

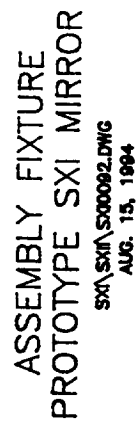


1. MATERIAL ALUMINUM ALLOY 6061-T6 PER 68-4-230/11 REMOVE ALL BURRS AND BREAK SHARP EDGES.
2. 3. 4.



ASSY FIXTURE (OPTION: 2)
PROTOTYPE SXI MIRROR

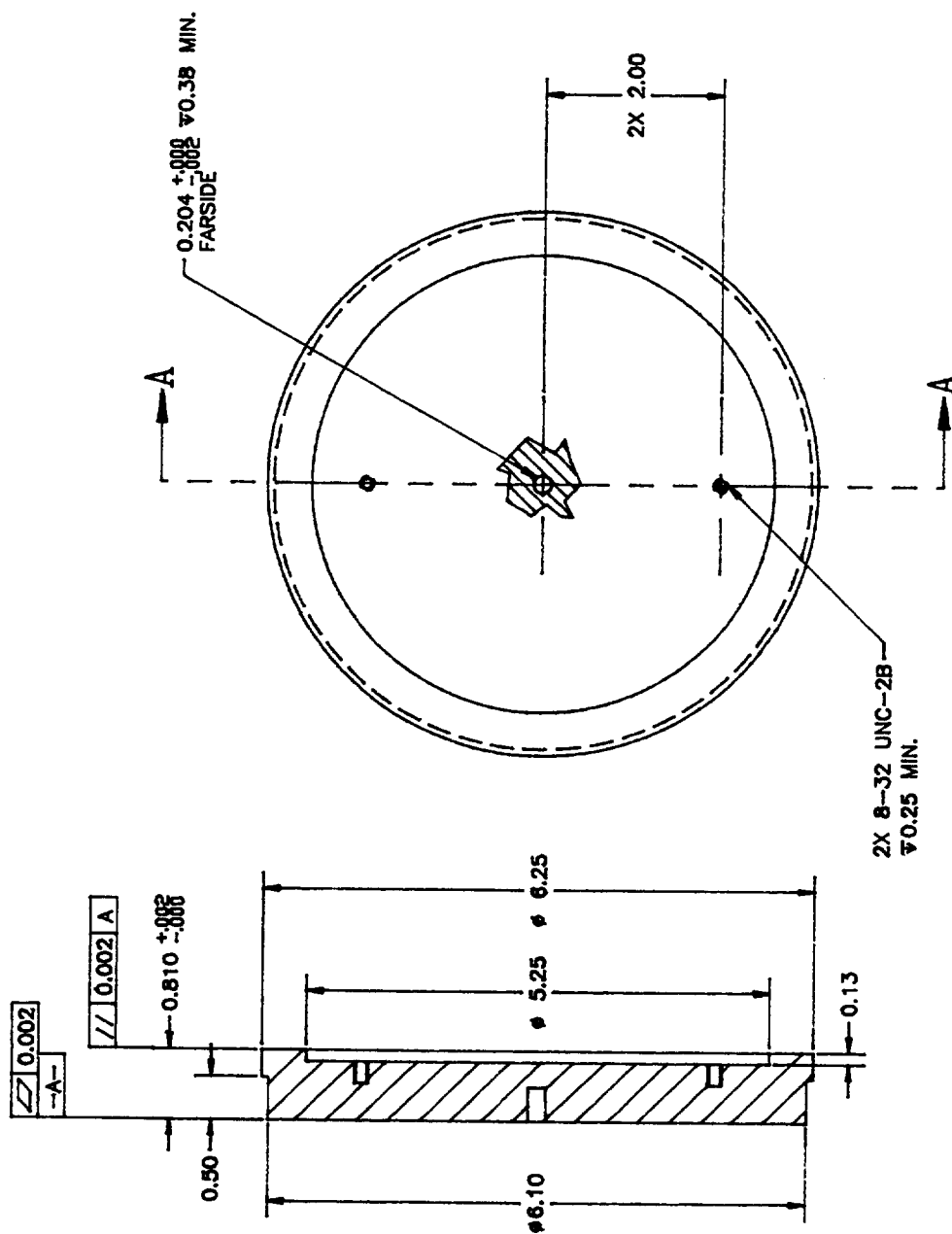
SXI/SXI/SX0001.DWG
AUG. 19, 1994

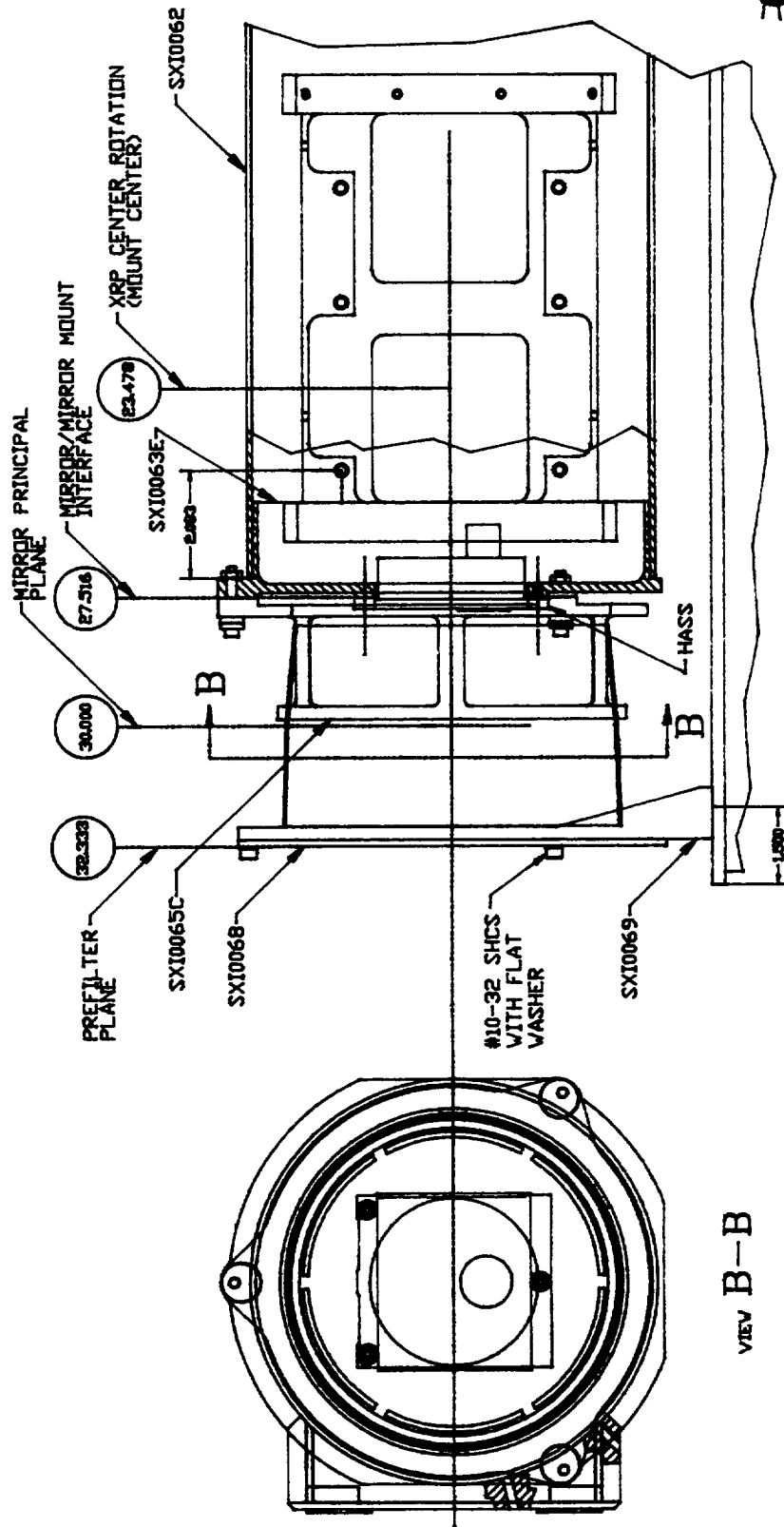


NOTES



1. MATERIAL: ALUMINUM ALLOY 6061-T6
PER 60-A-ES0/11
2. REMOVE ALL BURRS AND BREAK SHARP
EDGES.
3. USE ALL MACHINED SURFACES UNLESS
OTHERWISE SPECIFIED.
4. ALL FILLET RADII ARE TO BE .06 MAX,
UNLESS OTHERWISE SPECIFIED.





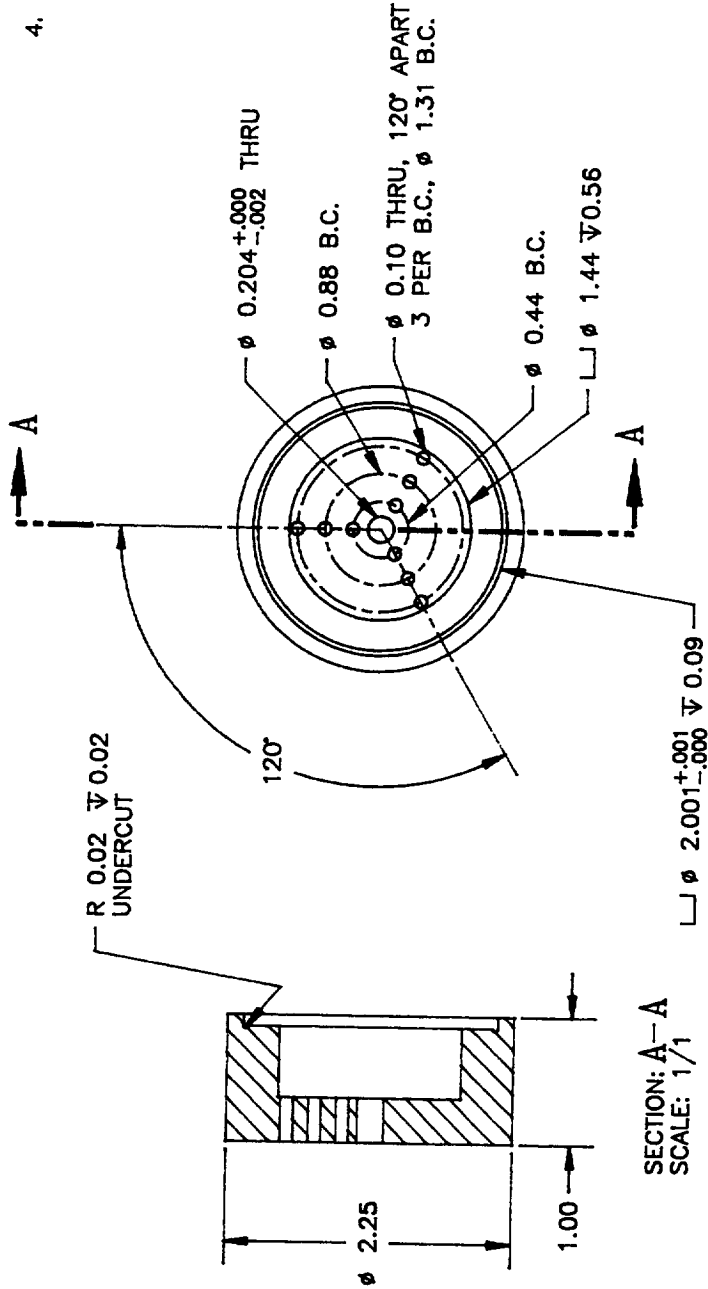
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University of Alabama in Huntsville
Huntsville, AL 35894

SXI PROTOTYPE
ASSEMBLY
10/10/93
SX10094.DWG

NOTES:



1. MATERIAL: ALUMINUM ALLOY 6061-T6
PER QQ-A-250/11.
2. REMOVE ALL BURRS AND BREAK SHARP
EDGES.
3. 125/ ALL MACHINED SURFACES UNLESS
OTHERWISE SPECIFIED.
4. ALL FILLET RADII ARE TO BE .06 MAX.
UNLESS OTHERWISE SPECIFIED.



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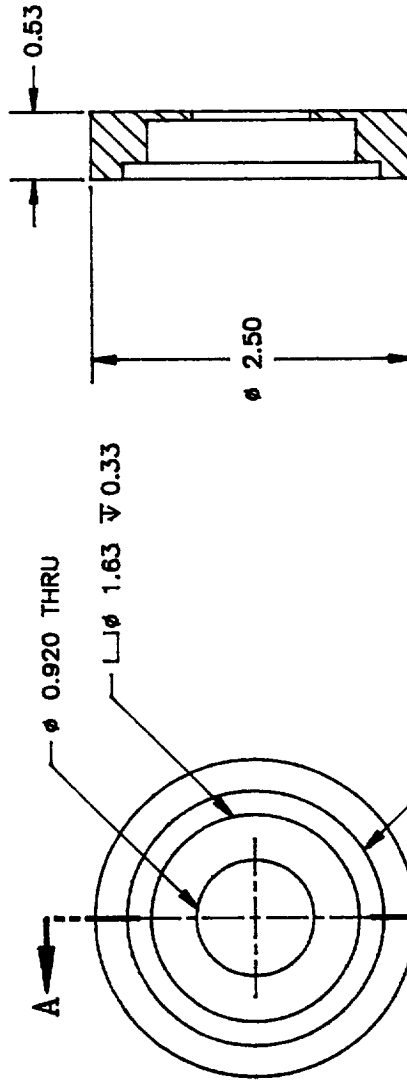
DM FIXTURE SXI FIBER OPTICS TAPER

SXI\SXI\ SXI0096.DWG
AUG. 9, 1994

NOTES:



1. MATERIAL: CPVC PLASTIC.
2. REMOVE ALL BURRS AND BREAK SHARP EDGES.
3. $125\sqrt{\text{R}}$ ALL MACHINED SURFACES UNLESS OTHERWISE SPECIFIED.
4. ALL FILLET RADII ARE TO BE .06 MAX. UNLESS OTHERWISE SPECIFIED.



SECTION: A-A
SCALE: 1/1



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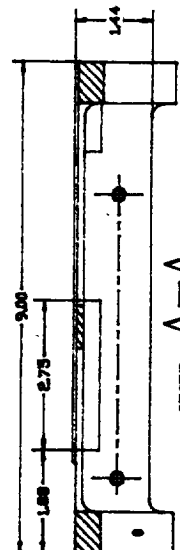
COATING MASK SXI FIBER OPTICS TAPER

SXI\SXI\ SXI0098.DWG
AUG. 10, 1994

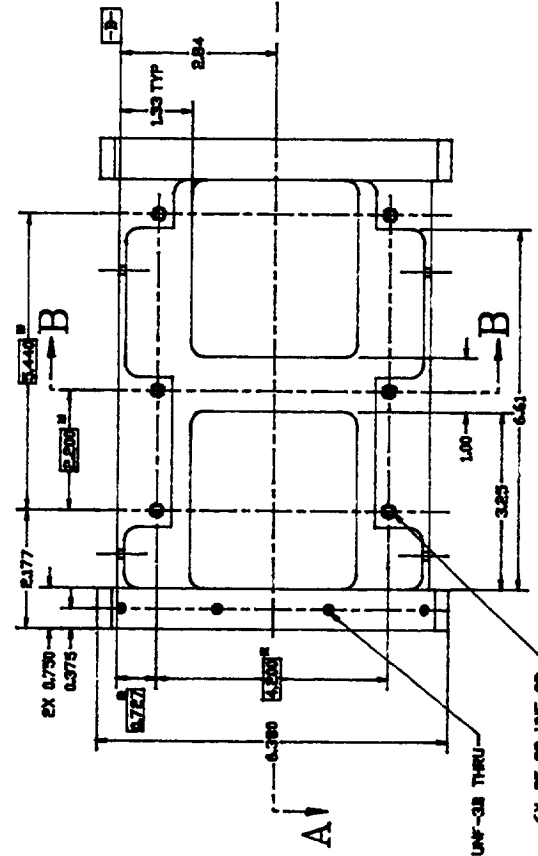
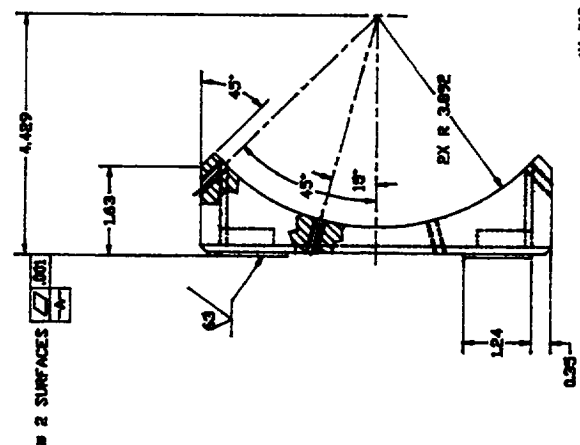
NOTES:



1. MATERIAL ALUMINUM ALLOY 6061-T6 PER QQ-A-250/11
2. REMOVE ALL BURRS AND BREAK SHARP EDGES
3. UN/ ALL MACHINED SURFACES UNLESS OTHERWISE SPECIFIED
4. ALL FILLET RADI ARE TO BE .25 MAX UNLESS OTHERWISE SPECIFIED
5. (R) INDICATES CRITICAL ATTRIBUTES BEFORE FINISH MACHINING STRESS RELIEVE AT 340° F FOR 4 HOURS



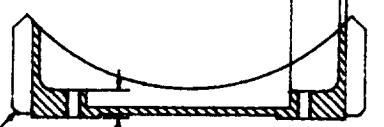
SECTION A-A
SCALE 1/1



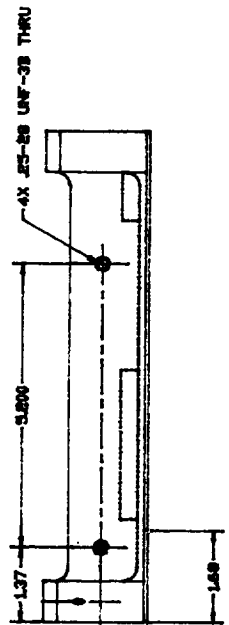
4X #10-32 UNF-3B THRU

6X .25-28 UNF-3B THRU

12 X 45° CHAMFER



SECTION B-B
SCALE 1/1



SX167863

PROTOTYPE
TELESCOPE
MOUNT (SX16)

SX167863

1/1

APPENDIX 3

FABRICATION AND PLATING PROCEDURES



29 September 1994

The University of Alabama in Huntsville

Process for Fabrication of Ceramic Contact Ring S435002-817
and S435002-818

1.0 DISCUSSION:

The ceramic insulator is bought from INSACO, Inc., Quakertown, PA per drawing. S435002-817. The tolerance and quality have been acceptable within this drawing and represents excellent product control. Attempts to alter the thickness at MSFC by lapping were not successful indicating the parts must be ordered to specific drawing dimensions and tolerance.

The tolerance on parallelism and flatness must be reviewed and the final drawings must call for required tolerances. These dimensions are not on the presently available S435002-818 drawing. The tolerance of 0.001 inch parallelism and 0.0005 flatness need to be reviewed since marked copies show 0.0005 and 0.000050 inches respectively.

The contact ring (S435002-818) is fabricated by coating and etching processes similar to microcircuit and printed wiring board procedures (PWB).

1.1. Inspection and Acceptance of S435002-817: MSFC

All dimensions and tolerances at this stage should be met by INSACO, Inc. MSFC acceptance should be the three radii (diameters), parallelism of each side and the flatness. The radii can be measured with micrometers. The parallelism can be measured on a granite flat plate with a micrometer height gauge such as Trioptics Spherometer or a measuring microscope such as the available Klinger at UAH. The flatness is more difficult and needs to be verified prior to the parallelism. Four traces of each side using a profilometer such as the Rank Taylor Hobson Talysurf used by UAH for the engineering models, will provide this data. After the heavier copper coating is applied, it will be necessary to lap and remeasure the parts to achieve the same flatness and parallelism.

1.2 Ceramic Substrate Inspection: INSACO Inc. 10 PIECES

Insaco shall provide individual component dimensional inspection data in an approved MSFC format.

MSFC is to order the parts and perform individual part incoming inspection including X-ray requirements.

2.0 Coating Process: UAH

2.1 Adhesion Coating 10 PIECES

Evaporate chromium 200 - 500 angstroms plus 1500 - 2000 angstroms of copper. Each side to be coated plus the extended end must be coated by tilting the part.

2.2 Sample test 2 PIECES

Two parts will need to pass an adherence test per MIL-G-45204C section 4.5.2.3 Baking Tests. Bend tests are not applicable. This test shall be monitored on the two test parts and the data recorded for MSFC QC.

3.0 Copper Electroplating and Lapping: UAH / MSFC 8 PIECES

3.1 Copper plating requirements

3.1.1 The copper plating shall be per MIL-C-14550, Revision B, Amendment 3, 20 Mar 87 or later as applicable.

3.1.2 The electroplated copper must adhere to the vacuum evaporated copper. The deposit thickness is to be 0.0015 +/- 0.0003 inch.

3.1.3 The chemical analysis shall include copper metal, sulfuric acid, chloride and a known addition of chemical brightener suitable for high quality printed wiring board (PWB) fabrication and shall be performed by MSFC.

3.1.4 Two pieces must pass adherence test per MIL-G-45204C or tape pull test for paint equivalent per MSFC.

3.2 Lap and Inspect Thickness and Flatness: UAH 6 PIECES

3.2.1 Lap with 3 micron aluminum oxide polishing compound on glass flat until thickness and parallelism tolerance is met. Remove equal amounts from each side. Measure using surface height gauge such as a spherometer.

3.2.2 Lap with 1 um aluminum oxide polishing compound until flatness requirement is met. Clean part prior to continuing. Measure using form profilometry such as Rank Talor Talysurf. Remeasure parallelism at this point. Record all data for review by MSFC QC.

3.3 Cleaning and Inspection: MSFC and UAH 6 PIECES

UAH shall clean and inspect parts after all lapping and inspection is complete. UAH is to approve inspection prior to sending to MSFC. MSFC to approve inspection document to be delivered to Max Levy, Inc.

4.0 Masking and Etching Process: Max Levy Inc. 6 PIECES

- (1) The photomask must adhere to the copper plated parts and minimize undercutting.
- (2) Parts must be cleaned to specification and inspected prior to this subcontractor stage.

4.1. Prepare dense photomask with PWB procedures: Max Levy, Inc.

- 4.1.1 Perform Incoming Inspection and record data. Notify MSFC QC and UAH if discrepancies are noted.
- 4.1.2 Plot artwork.
- 4.1.3 Photoreduce to tolerance if oversize process is used.
- 4.1.4 Apply to part using alignment marks for reference.

4.2 Inspection: Max Levy, Inc.

- 4.2.1 Inspect masked parts and record discrepancies individually. Subcontractors Inspection System is to be currently approved as conforming to the requirements of MIL-I-45208A by at least one other government (DOD or NASA) Contractor such as, but not limited to Ball Corporation, Hughes Aircraft Co., Martin Marietta (Lockheed Martin) or Northrup Corp. Evidence of such current approval may be certified copies of acceptance letters or some other form agreed upon by MSFC or UAH. Current conformance is subject to review and approval by MSFC or UAH at all times prior to and during the performance of the [proposed] contract.
- 4.2.2 Subcontractors Calibration System is to be currently in conformance to the requirements of MIL-STD-45662 and will be subject to review and approval by MSFC or UAH. The Subcontractor's signed certificate must indicate:
 - (1) Traceability to the National Institute and Standards
 - (2) Tool or gage number
 - (3) [Proposed] contract number.

4.3 Etch Pattern in Copper: Max Levy Inc. 3 PIECES

- 4.3.1 Use PWB process - either ferric chloride or ammonium persulfate to be considered. Note that separate chromium etchant such as potassium permanganate or HCl may be required to remove chromium adhesion layer.
- 4.3.2 Remove masking material. Inspect for signs of undercutting. Notify MSFC of results before continuing.
- 4.3.3 Repeat 4.3.1 and 4.3.2 with 3 pieces if unacceptable.

- 4.3.3 Clean and inspect prior to packaging for shipment for gold plating. Shipping package to contain dessicant.

Note:

- (1) Max Levy may quote gold plating since cyanide or non-cyanide based plating is acceptable.
- (2) Non-cyanide processes will be used if MSFC/UAH performs the gold plating.

- 4.3.4 Provide inspection documentation per MSFC contract deliverable.

- 4.3.5 INSPECTION OPTION: MSFC or UAH may add source inspection at subcontractor's facility. The inspection is to be performed by the Subcontractor and shall be subject to witness by MSFC or UAH authorized Quality Representative. The Subcontractor shall contact the appropriate representative as specified in advance of completion to scheduled Source Inspection and the agreed upon inspection/test points.

- 4.3.6 The Subcontractor shall have available and present upon request, documentation of his inspection/test. This may be used for acceptance of parts. Required documentation for shipment shall be completed and signed by the subcontractor's authorized Quality personnel and available for MSFC, or UAH Quality Representative's review.

5.0 Gold Plate: UAH / MSFC Materials 4612 3 PIECES

- 5.1 Non-cyanide process for MSFC/UAH is required such as Technic Au-25 high purity gold.

- 5.1.1 MSFC to provide analysis of solution for gold content and pH prior to plating of parts.

- 5.1.2 Gold is to be plated per MIL G-45204C Amendment 3 , Type I or III, Class A or B.

- 5.1.3 Clean per MFSC

- 5.1.4 Package per MSFC

GOLD PLATING PROCEDURES FOR S435002 - 805, 806, & 811

Description: Provide plating materials and procedures for coating the 805, 806, and 811 beryllium copper components for the X-ray detector.

- A. Electropolish sharp edges from 805 and 806
75 vol% H_3PO_4 at room temperature
- B. Plate nickel 1.0 to 1.5 microns thick
Barrett Sulfamate low stress nickel
pH - 4.0, Temperature 50 Deg. C, NTSA and coumarin additives to level deposit
- C. Plate gold 1.0 to 1.5 micron thick over nickel (no thickness called out on nickel so equivalent thickness was used per discussion)
Technic alkaline sulfite gold process;
1.0 - 1.5 Oz/Gal gold, pH 9.5 to 10.5 with 50 to 100 ppm proprietary Technic brightner for smooth deposit.

I. Contact Ring S435002-805

Calculate approximate area - Area = 2.61 cm^2
Electropolish to remove sharp edges and provide electroactive clean surface.

Note two groups are denoted I, & II

Group I;

Electropolish 1.0 minutes at 6.0 volts (about 0.75 - 1.0 microns) and inspect (individually)

Group II;

Electropolish to 4 microns below nominal thickness for better edge (individually)

Plate 1.0 to 1.25 micron nickel (2 microns on part thickness) @ 10 mA/cm^2 for 2.5 - 3.0 minutes (four in group)

Plate 1.0 to 1.5 microns gold (2 microns on part thickness) @ 5 mA/cm^2 for 6.0 - 9.0 minutes (four in group).

II. Contact Ring S435002-806

Calculate approximate area - $\text{Area} = 4.25 \text{ cm}^2$

Electropolish to nominal thickness to remove sharp edges and provide electroactive clean surface.

Electropolish 3.0 minutes at 6.0 volts and inspect (individually)

Electropolish to approximately 4 microns below nominal thickness (individually)

Plate 1.0 to 1.25 micron nickel (2 microns on part thickness) @ 10 mA/cm^2 for 2.5 - 3.0 minutes (individually)

Plate 1.0 to 1.5 microns gold (2 microns on part thickness) @ 5 mA/cm^2 for 6.0 - 9.0 minutes (individually).

III. Contact Finger S345002-811

Calculate approximate area - $\text{Area} = 1.59 \text{ cm}^2$

Electropolish 1.0 minutes at 6.0 volts and inspect (four in group)

Plate 1.0 micron nickel (1.5 - 2 microns on part thickness) @ 10 mA/cm^2 for 2.5 - 3.0 minutes (four in group)

Plate 1.0 to 1.5 microns gold (2 microns on part thickness) @ 5 mA/cm^2 for 6.0 - 9.0 minutes (four in group).